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Meeting of the Cotton States Branch

The Cotton States Branch of the American Association of Economic Entomologists will hold a war conference on entomology in New Orleans, Louisiana on February 2 and 3 1944. The Jung Hotel has been selected as headquarters.

Erratum

An error in the paper by Seiferle, Johns and Richardson, "The Alkaloids of American Hellebore and their Toxicity to the American Cockroach," Jour. Econ. Ent. 35(1):35–44 (1942), has been called to my attention. The error is in the formula for pseudo-jervine, p. 38, col. 2, line 8 from bottom: it should read $C_{33}H_{49}O_8N$.

E. J. Seiferle

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Terminology of Insecticides, Fungicides and Other Economic Poisons

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There is familiar experience back of the terminology or nomenclature of common insecticides and other agricultural chemicals, but in the past few years many complexities have arisen. The situation may become serious when legal problems are involved. Not infrequently problems have been settled through conference between government officials and manufacturers so that correct terminology becomes familiar to the latter. Unfortunately the benefit derived from these conferences does not always come to the attention of others whom it may concern. It has happened that some time after a term has been clarified by resorting to legal regulation, a scientific treatise has appeared continuing the old misleading or ambiguous term. Few realize how solidly a term misused by an accredited technical investigator may become entrenched, and how difficult such an error is to correct.

Most entomologists and plant pathologists carefully report the exact species involved in their investigations and similar specificity is needed in mentioning a product or a chemical used in their experiments. Much of the value of some investigations has been lost due to ambiguity in terminology of insecticides, fungicides and other economic poisons (pest control materials). Use of incomplete, ambiguous or confusing terms should always be avoided. Some progress in this direction has been made. There have been great improvements in correct usage of such technical terms, and the writer has been encouraged to record illustrations that may be helpful. Difficulties in usage due to carelessness are correctible, but some are due to inadequacy of language. In such cases one can only recognize that ambiguity exists.

DEFINITION OF COMMON TERMS.—Such words as *extender*, *diluent*, and *filler* are generally understood and used without confusion, and call attention to the role of an inert ingredient as a space filler in dusts. Although the term *carrier* generally signifies an inert ingredient, it implies the possibility of a more positive function, for example, the acidic or basic nature of certain carriers has a marked effect on the value of some active ingredients, and to that extent the substances deviate from the commonly accepted concept of an inert ingredient. As knowledge of the specific relations and functions of all the components of a dust increases, more terms may be required, each to be used with a precise meaning. Some terms are occasionally used in advertising literature in an ambiguous manner and unless accurately defined are without specific significance, for example: "Superfine," "Colloidal," "Penetrant," "Buffer," "Deposit builder," "Improver," "Dissociant," Wax solvent," "Disperser," "Safener," "Conditioner," and "Lubricant." They are mostly used only as a vague connotation of a desirable characteristic and have no proper place in scientific literature unless adequately defined. This has been done in the case of certain of these terms. For example, in 1938 with respect to sulphur the writer proposed that to be called "Dusting," 95 per cent of the sulphur should pass a 200-mesh screen; "Fine," 90 per cent should pass a 325-mesh screen; and "Superfine," 98 per cent should pass a 325-mesh screen. A product to be described as "Colloidal" should have the properties understood by

the physical chemist as being characteristic of colloids. The federal government has taken action against products labeled as being colloidal that actually consisted mainly of particles visible with the microscope and not sufficiently fine to be designated by this term. It is inappropriate to refer to a finely divided substance as colloidal unless the major part by weight is comprised of particles with a diameter not greater than 10^{-5} centimeter (0.1 micron). The term "Penetrant" is sometimes used to describe a substance that facilitates movement of an emulsion or other liquid into crevices or pores such as in soil or bark, to secure deeper penetration. A "Buffer" is a substance which when dissolved in water produces a solution which resists a change of hydrogen ion concentration when the solution is subjected to gain or loss of acid or alkali.

The term *adjuvant* or *accessory substance* signifies any material added to a primary pest control chemical or product when a function is not being particularly emphasized for it. In some cases a function cannot be defined in closer terms for lack of sufficient information. In general, no chemical action is involved between an adjuvant and any other component of a mixture, but the importance of an adjuvant is reflected in the efficacy of the products of which it is a part. Several terms are used to emphasize special functions of adjuvants, for example: *intensifiers, activators, emulsifiers, deflocculators, detergents, wetters, spreaders,* and *stickers* or *adhesives.* An *intensifier* is a substance a small quantity of which added to a material of low efficacy affords a pest control product effective for the economic poisons purpose intended. An example would be Pyrethrum Extract 20 when added to petroleum oil to produce fly spray. Such a substance is sometimes called a fortifier. An *activator* is a substance which may have little or no effectiveness of its own in pest control, but which increases the effectiveness of some other component of a pest control product. Synergism is a special case in which the substances involved are active ingredients, mixing of which produces a more than additive potency. The opposite effect is antagonism. An *emulsifying agent* is a substance which aids in the production or maintenance of a dispersion of one liquid within another. A *deflocculating agent* is a substance which aids in the production or maintenance of a dispersion of a solid within a liquid. A *detergent* is a substance used in aqueous medium to facilitate removal of foreign matter from solid material as, for example, in removal of spray residue. A *wetting agent* is a substance which increases the tendency of a liquid to make complete contact with the surface of a solid, so that no dry area may remain. A *spreader* is a substance which increases the area that a given volume of liquid will cover on a solid, or on another liquid. A *sticker* or *adhesive* is a substance which increases the firmness of attachment of finely divided solid material to a solid surface. Elaborations of these definitions are outside the scope of this paper, but some are described extensively in a series of articles having the general title, "Factors Concerned in the Deposit of Sprays," for the first number of which see Hensill, G. S. and Hoskins, W. M., JOURNAL OF ECONOMIC ENTOMOLOGY (1935) *28*, No. 6, page 942. The effects of adjuvants differ under different circumstances, and sometimes one may have properties that qualify it under several of the definitions. In some cases a material mixed with one adjuvant makes an efficient product, but when mixed with a different adjuvant in the same proportion, results in a product of little or no value as an economic poison.

Emulsifiers may vary as to their compatibility with different products. For example, petroleum spray oil containing a given emulsifing agent may afford good results when used with water from one source and give poor results or be hazardous when used with another. Results may differ depending upon whether or not a constituent is adsorbed or absorbed, as the oxidation, volatility and rate of availability of a toxic substance may vary whether it is primarily on the surface (adsorbed) or located throughout each particle of a carrier (absorbed). This is another feature of the nature of insecticide dusts that is receiving increasing attention. When the effectiveness of an economic poisons spray or dust depends largely upon the adjuvant, the adjuvant is regarded as an economic poisons product and requires compliance with the Economic Poisons Article of the Agricultural Code of California. No attempt has been made to include in this paper a com-

pilation, much less definitions, of all terms used in economic poisons work.

AMBIGUOUS TERMS.—There are many cases where ambiguity is not the fault of anyone in particular. Frequently it is necessary to make decisions on insecticide terminology before adequate information is available on the chemical constitution of a material. A case in point is the product formerly known as commercial calcium arsenate. It is manufactured with a standard composition to guarantee tri-calcium arsenate 70 per cent. It may not be labeled "Calcium arsenate" which would indicate a relatively pure compound, but an acceptable name is "Calcium arsenate and other calcium compounds." It has long been guaranteed in terms of tri-calcium arsenate, but evidence now indicates that it may include one or a mixture of the several basic calcium arsenates. In that event, publication of tri-calcium arsenate percentages might be misleading by implication that one containing 71 per cent was slightly better than one containing 69 per cent, whereas one containing 69 per cent of the most active ingredient the nature of which is as yet uncertain might be of greater value than another with a higher calculated percentage of tri-calcium arsenate. In time a more scientific terminology and statement of ingredients for this product may be possible. Incidentally, the same line of argument could be applied to calcium arsenite, which is highly toxic to plants and is used principally as an eradicant spray on dormant trees to disinfect plant twigs attacked or killed by some fungi.

There have been a number of cases similar to that of calcium arsenate where we have had to accept group or collective names even though they did not accurately describe the material. To illustrate, dry sodium arsenate may designate a number of different chemical compounds as does the term sodium arsenite. Certain federal authorities accept the term sodium arsenite to mean sodium metarsenite ($NaAsO_2$). In order to avoid ambiguity in California sodium arsenite solution is guaranteed in terms of arsenic trioxide. Zinc sulphate, manganese sulphate, iron sulphate, and copper sulphate may exist in several hydrated forms. For example, copper sulphate may be of anhydrous, monohydrate or pentahydrate form. A yardstick for products of this kind is to require metallic or other chemical equivalent to be stated on the label.

NICKNAMES.—Nicknames are misleading. Dry lime sulphur is too frequently referred to as "Dry lime." Both barium fluosilicate and barium carbonate have been loosely referred to as "Barium." In answer to a question if there was a spray residue tolerance for barium on vegetables, a man replied, "Yes, it is two hundredths of a grain per pound," which is the tolerance for fluorine. There is no tolerance established for barium. The abbreviated term "Arsenate" or "Arsenite" is indefinite when used to refer to a specific chemical, as it might refer interchangeably to a sodium, zinc, calcium, manganese, or other compound. It is not proper to refer to calcium arsenate as "Calcium." Similarly, it is inappropriate to refer to lead arsenate as "Lead," or to carbon disulphide as "Carbon" for one might think of lamp black. The term "Zinc" is confusingly used to designate zinc oxide or zinc sulphate. The term "Blood" is often used incorrectly to refer to *blood albumin spreader*, and *calcium caseinate spreader* ought not be shortened to "Casein" or referred to as merely "Spreader." The term *sulphur* means elemental sulphur and should not be used when reference is had to *combined sulphur*. For example, when one has stated gypsum or ammonium sulphate he has included the *combined sulphur* of the sulphate radical, and it is not permissible in addition to claim that the material "contains sulphur" as this would imply the presence of elemental sulphur. Aside from avoiding nicknames, great care is required in pronunciation and spelling to distinguish between similar legitimate terms such as *ammonium sulphate*, a fertilizer; and *ammonium sulfamate*, a weed killer. A somewhat similar but not identical liberty is discussed later with regard to use of nicknames for brand names.

The names of synthetic organic compounds are sometimes long and complicated because they designate much detail of chemical structure. Audiences frequently smile when one mentions beta-butoxy-beta'-thiocyanodiethyl ether or dinitro-ortho-cyclohexyl phenol. Nevertheless, there are many thousands of compounds which chemists must differentiate in similar manner. The term "Dinitrophenols" has been indiscriminately used

in publications to refer to a number of different insecticidal compounds now on the market, such as dicyclohexylamine salt of dinitro-ortho-cyclohexyl phenol and sodium dinitrocresolate. Actually dinitrophenol designates a distinct, quite different chemical composition. When 2, 4-dinitrophenol was used as an obesity cure a few years ago severe injury resulted, and a separate law carefully worded not to apply to economic poisons was enacted restricting its medicinal usage. It is incorrect to use the term "Dinitrophenols" as a class name for compounds that contain any other group in addition to the two nitro groups.

In many cases a relationship has been established between chemical structure and known properties. If a compound has a chemical structure containing certain known groupings of atoms, the substance may be predicted as likely to have the characteristics of an insecticide; another known grouping, a dyestuff; or still another, as possibly having other industrial application. The class of compounds derived from the dinitrophenols seems to have both chemical and physiological properties in common. Class terms are usually created to avoid awkward expressions and repetition, and a term such as *derivatives of nitro phenols* may meet the situation.

Lethane is another term incorrect use of which has caused confusion, for no such product as "Lethane" is registered for sale in California. There are registered *Lethane 384*, *Lethane 384 Special*, and *Lethane 60*, all different products. One should take cognizance of even smaller differences in brand names. Unless a specific product is mentioned by its complete brand name or its common chemical name if possible, there is no certainty as to the material used. In lieu of a more exact expression the active ingredients in some of the mentioned "Lethane products" have been referred to as *Organic thiocyanates containing combined nitrogen xx per cent*, when proper figures are included in lieu of "xx." A more specific description is *Beta-butoxy-beta'-thiocyanodiethyl ether*, or *Beta-thiocyanoethyl esters of aliphatic fatty acids averaging 10 to 18 carbon atoms*, or a mixture of these. For these or similar products more exact terms may be possible, and the most nearly accurate name known should be used.

MISLEADING TERMS.—There are a number of terms in insecticide terminology, the use of which should be discouraged as misleading. For example, use of the obsolete name "White arsenic" instead of the term arsenic trioxide and of "Copperas" instead of the term ferrous sulphate has caused considerable confusion in the minds of consumers, and these terms now have been abandoned by most manufacturers. Years ago one manufacturer insisted that a competitor "was selling sodium fluoride as a rat and mouse repellent powder," and was convinced that he was wrong only when shown "Sodium silico fluoride" on the label. The term *sodium fluosilicate* has replaced "Sodium silico fluoride," to avoid confusion with sodium fluoride. Similarly *sodium fluoaluminate* is used in lieu of "Sodium aluminum fluoride." *Flour sulphur* refers to ground lump sulphur, whereas *flowers of sulphur* is a sublimed product with particles of a different type from those of ground sulphur. The term "Copper oxide" is indefinite and may refer to the cupric form which is black copper oxide not generally used as a fungicide. That used as an economic poison is cuprous oxide.

Chemical names as they exist and are used today have been developed as knowledge has increased. Years ago acid lead arsenate was the only type of lead arsenate produced commercially, and was called merely "Lead arsenate." Later *basic lead arsenate*, preferable for use on certain types of foliage, was produced. After several cases of mistaken identity and serious injury involving substantial financial losses where so-called "Lead arsenate" was sold in lieu of basic lead arsenate, we insisted that the name "Lead arsenate" be changed to read standard lead arsenate or acid lead arsenate. Since many manufacturers thought farmers would be prejudiced against using on their trees any product the name of which suggested acid, the term *standard lead arsenate* always has been preferred. The economic poisons industry has cooperated in every effort to lessen mistakes which might result in any injury.

The word "Nicotine" was formerly loosely used, and there has been developed a differentiation between *nicotine alkaloid* and *nicotine expressed as alkaloid*. As a contact insecticide or as a stomach poison

a product may contain either free nicotine alkaloid or nicotine in chemical combination. Some fumigant type agricultural insecticidal dusts contain free nicotine alkaloid in an alkaline carrier, whereas most contain chemically combined nicotine, with a suitable carrier to free it. In the latter case it is customarily added to the carrier as *nicotine sulphate solution*, which is largely sold in the form of proprietary solutions. This has been sometimes mistakenly referred to as "Nicotine sulphate," which would erroneously indicate nicotine sulphate approximately 100 per cent.

The minimum concentration at which a chemical product ceases to be eligible for unqualified labeling has been given much thought. For example, it is not proper to designate simply as "Formaldehyde" a solution containing formaldehyde 37 per cent, nor simply as "Sodium fluoride" or even "Sodium fluoride dust" a powdered preparation containing sodium fluoride with talc, but these may be called *formaldehyde solution*, and *sodium fluoride and talc*, *sodium fluoride and talc mixture*, or *sodium fluoride and talc dust*, or by similarly acceptable qualified terms indicating dilution, admixture, or physical condition. It is the view of federal officials that a descriptive name should not be used for a product unless it is completely descriptive, and if a reasonably completely descriptive name is too long for use on a label or in advertising of an economic poison the practical thing is to employ a name which is not descriptive and follow the name with a statement of composition, such as "Contains sodium fluoride." California law does not necessarily require that the name of an inert ingredient be divulged. If the ingredients are completely divulged on a label, one should be more lenient in accepting a name than if the composition were not disclosed to the user. The words, dust or powder, indicate that an economic poison is in a form suitable for insecticidal dusting or that it is finely divided. Authorities agree that when a second substance has been added, the name of the resulting product shall not imply that it consists of a single component. A proper labeling is illustrated by *standard lead arsenate with adhesive*. On the other hand, common impurities may be great enough to rule out a name involving purity. More than 5 per cent impurities may prevent a product being acceptably called by a name implying purity. Wherever possible coordination of state policy in such matters with the federal government is achieved. In ordinary usage the expression nicotine, derris, or pyrethrins dust is often used to designate any dust containing the stated material as the principal active ingredient or ingredients. A more nearly accurate use would be to speak of these as dust *mixtures* whenever a toxic substance is mixed with other ingredients, and use of the word *mixture* to indicate the presence of another ingredient is an acceptable term in California, inasmuch as in general the statement of ingredients will indicate the extent of deviation from the pure named active ingredient or ingredients.

In 1940 the name *bordeaux mixture* or "Bordeaux" was being loosely used in California to designate sprays of zinc, manganese, and iron sulphates, together with hydrated lime, for use on citrus trees, to alleviate certain plant nutritional deficiency disorders. The sprays were often combined with varying amounts of copper sulphate and hydrated lime for its value as a fungicide, but they were used separately as well. After discussion it seemed clear that a specific significance should be attached to this important agricultural substance and that California should restrict use of the term to its original meaning. Accordingly it was agreed that the term *bordeaux mixture* or "bordeaux" in any form, combination or spelling shall refer only to the reaction products of copper sulphate and lime in any suitable form and water, and cannot be accepted where no copper is present, nor can the term be extended to new variations, such as to mixtures of zinc and iron salts. We ultimately ruled that the term must not be applied to an economic poison containing any zinc, manganese, or iron salt added to a copper sulphate pentahydrate (bluestone) and lime preparation, that a term such as "bordeaux mixture with zinc" is not acceptable, and that modified materials shall have modified names stating what they are, for example, *zinc and copper sulphates mixture*. Occasionally an author uses the second figure in a bordeaux mixture formula, such as 8-8-100, interchangeably to mean calcium oxide, CaO, or hydrated lime, $Ca(OH)_2$. The form of lime should be

stated along with the formula, or plant pathologists should reach an agreement as to what the formula should signify, in order that this important matter be not left in doubt. To afford the same chemical equivalent, one-third more by weight is required of calcium hydroxide than calcium oxide. In order to designate bordeaux mixture standards the writer employs present accepted usage of the more convenient unit such as 8-8-100 instead of the old 4-4-50, the 50 referring to the 50 gallon capacity old-fashioned barrel spray rig. Usage of 100 gallons as the unit is meeting with increased favor as modern commercial spray rigs have tanks with a capacity of multiples of 100 gallons. Carelessness with regard to the significance of the figures in bordeaux mixture formulas may account for conflicting results.

Many can remember the old confusion with regard to lime-sulphur solution, when in California it was necessary to resort to a legal definition of the product in order that use of the term might have some definiteness of meaning. The term *lime sulphur solution* is reserved for solutions containing calcium polysulphide not less than 29 per cent and having a density of not less than 31° nor more than 33° Baumé at 60° F. Specifications had to be set up defining creosote, sodium arsenite solution, and some other substances as well as grades of petroleum spray oils. It has been possible from time to time as methods of analysis have been developed to establish further standards. Before pyrethrins analyses were officially recognized, many applauded early adoption of a so-called standard pyrethrum extract 20 to 1 product which gave the kerosene extractive of twenty pounds of pyrethrum flowers to one gallon of extract. This was a step in the right direction, but was still ambiguous inasmuch as the twenty pounds of flowers could vary greatly in pyrethrins content, and the efficiency of extraction could differ. The pyrethrins may vary from 0.6 per cent in Dalmation flowers to 1.3 per cent in those from Kenya. Our analyses have shown some so-called 20 to 1 extracts to contain but half the percentage of pyrethrins contained in other such products. The legal method for determination of pyrethrins I in pyrethrum powder is that designated as "Official" by the Association of Official Agricultural Chemists, and any guarantee in California is checked by this method.

NAMES OF BOTANICALS.—The term *extract of pyrethrum* should not be shortened to "Pyrethrum." "Extract" is indefinite until the pyrethrins are guaranteed by percentage. The federal government accepts *insect powder* to mean powdered pyrethrum flowers, and the unqualified term cannot be acceptably used to refer to any other material. An appropriate term might be *pyrethrum insect powder* since there are other just as truly insect powders, for example, *sodium fluoride insect powder*, and *derris root insect powder*. In referring to botanicals containing extractives of rotenone bearing roots accuracy requires use of the name of the particular root. Most rotenone containing products are derived from three different plant genera: *Derris* species grow in British Malaya, the Dutch East Indies, and the Philippines, and formerly constituted the most important source of rotenone. The common name, derris, always refers to plants of the genus *Derris*. *Lonchocarpus* species are found in South America and now constitute the principal source of rotenone in the United States. These species have a number of different common names, depending upon the location in which they are found. For example, they may be termed cube in Peru; barbasco in Peru and Brazil; timbo in Brazil; haiari in British Guiana; and by various other names in other countries. *Tephrosia* species, which is synonymous with *Cracca* species, are found in North and South America, Africa, Asia, and Australia. These species may also be called cube and barbasco in Peru; timbo in Brazil; or barbasco in Guatemala, Colombia, and Mexico. Results published in the magazine *Soap and Sanitary Chemicals* (1942) *18*, No. 9, p. 95, indicate that the domestic plant *Tephrosia virginiana* may be successfully substituted for derris and cube roots to obtain sprays with a high degree of toxicity to houseflies. In critical testing a knowledge of just what plant is being used is important, because even though the rotenone content may be the same for the various roots, the extractives other than rotenone will differ to an important degree for a given percentage. For this reason, in addition to rotenone percentage, it is important that the root be named in stating derivation of *other ethyl ether extractives*, sometimes

called "Rotenoids." The term "Rotenoids" is not synonymous with other ethyl ether extractives and applies only to rotenone-like substances other than rotenone itself, and it would be incorrect usage of the term "Rotenoids" to apply it to insecticidal compounds of an entirely different nature from rotenone that may occur along with rotenone in some plants.

Attempts at standardization of economic poisons of undeterminable composition have taken some interesting turns in recent years. In many cases it has been possible to give greater exactness to these by means of bio-assay methods such as Peet-Grady tests for fly sprays, and grains of red squill products per pound of body weight that will be lethal to white rats. Whether it be chemical or biological testing, it is of utmost importance that the analytical method used eventually be standardized.

PHENOLIC COMPOUNDS.—The term cresylic acid has been loosely used to include variable mixtures of many associated phenolic compounds, both from coal-tar oils and petroleum oil. The term "Carbolineum" has been used to refer to a general anthracene oil fraction or to an emulsified coal-tar oil, and should be clarified. The term "Crude carbolic acid" in the past has been used to designate coal-tar distillates of variable compositions of phenols and neutral oils so that under that terminology it might have been possible for a product labeled "Crude carbolic acid" to be almost wholly neutral oil and to contain practically no carbolic acid.

PETROLEUM SPRAY OILS.—Recognized types of petroleum oils for plant sprays are marketed under the terms spray oil emulsion, emulsive spray oil, and tank-mix oil. A *petroleum spray oil emulsion* is a mayonnaise-type emulsion of petroleum oil in water. Such a product contains oil approximately 80 per cent, and simply requires dilution with water before use. The more fluid ones are sometimes designated "Flowable." An *emulsive petroleum spray oil* is one in which an emulsifying agent soluble in oil has been added. Such a product contains petroleum oil approximately 99 per cent, and forms an emulsion upon addition to water with agitation. The term "Miscible oil" has been used to some extent to designate a dormant type emulsive product containing petroleum spray oil approximately 85 per cent with phenols and soap as emulsifying agents. This product was very important during the early period of spray oils but is seldom used now. It seems erroneous to refer to emulsive oils as "Soluble" inasmuch as they form emulsions and not solutions with water. *Tank-mix oil* is a term adopted to designate a petroleum spray oil to be used with an emulsifying agent and water, all of which are added to the spray tank and the mixture maintained as an emulsion or even dispersion by agitation during application. The terms "Straight oil" and "Unmodified oil," which may suggest crude oil, are hardly adequate, but are sometimes used in lieu of the more descriptive term *petroleum spray oil* in an attempt more clearly to differentiate it from emulsive petroleum spray oils and from petroleum spray oil emulsions. The term "Toxic oil" is misleading as it implies that oil itself is not toxic, and a satisfactory term to refer to rotenone and oil preparations is, for example, *petroleum spray oil and rotenone mixture*, *intensified petroleum spray oil*, or *petroleum spray oil with added toxicant*, the last terms having more general application.

Among the laity there is still considerable discussion of viscosities, but it is believed they are of secondary importance and greatest emphasis should be placed on distillation range. In California, foliage petroleum spray oils are classified into *light*, *light medium*, *medium*, *heavy medium*, and *heavy*, depending on the amount distilling at 636° F. Foliage spray oils that do not meet these distillation ranges must be labeled "Unclassified." Each class has a specified minimum *unsulphonated residue*.

In reference to a petroleum spray oil the term *unsulphonated residue* should be consistently used, although this has been sometimes stated in the literature as "unsulphonatable residue." The California Department of Agriculture method for determination of *unsulphonated residue* is recognized by the supplier and consumer of petroleum spray oils. It was reviewed and studied for several years by the American Society for Testing Materials, and the term and method were adopted in 1940 as official Method D 483–40. It was also approved as American Standard by the American Standards Association and designated ASA No. 00: Z11.41-1940.

Unsulphonated residue is a petroleum spray oil test developed from a method already in use nearly 40 years ago in the turpentine and the coal tar industries. In 1911, Mr. E. Bateman used this term in U. S. Forest Service Circular 191. Seldom, if ever, does a wood tar oil or a coal tar oil show any measurable unsulphonated residue. Unsaturated compounds of petroleum oil are those components not completely sulphonated or oxidized to a stable condition, and which have not been removed in the refining process. They have insecticidal value but are markedly toxic to foliage and plants. Many of these are removed by ordinary concentrated sulphuric acid under conditions of the unsulphonated residue test, and for practical purposes all are removed in the test by using 37 *N* H_2SO_4. The evolution of heat and sulphur dioxide during the test indicates extensive reaction rather than solution; however, the manner in which the constituents are removed is immaterial. The unreacted oil is read directly and reported as percentage by volume. Although the capacity of petroleum oil for reaction is augmented with an increase in the size of the molecule and the number of side chains attached, any percentage of higher saturated hydrocarbons which are sulphonated or dissolved by sulphuric acid is small and believed negligible.

Mr. G. P. Gray, a former Chief of the Bureau of Chemistry, who originally adapted the method to petroleum spray oils, used the term *unsulphonated residue*. The test is to determine degree of refinement and toxicity, the higher the unsulphonated residue the greater the refinement, and affords a clue to any toxicity of a petroleum spray oil to plants. For example, a petroleum oil that contains unsaturated compounds 20 per cent will have these removed in the test, and leave the saturated compounds or unsulphonated residue which will be read as 80. One containing unsaturated compounds 10 per cent would show an unsulphonated residue 90 indicating an oil less toxic to foliage.

When one uses the term *unsulphonated residue*, he is referring to that portion which remains unaffected by the official method, and this term is used when preparing tabulated data of the test. By using the term "Unsulphonatable residue," it is implied that no matter what is done, the petroleum oil residue remains unsulphonated under any and all methods and conditions. This is not true as different methods do not give the same result. Frequently it is difficult to determine the best term to designate an arbitrary test. *Unsulphonated* and "Unsulphonatable" may be thought of as past or future. As the terms are ordinarily used, they may be equally correct depending on one's starting point, but perhaps neither is exactly correct, except as a name. *Unsulphonated residue* is a standard test performed in accordance with a definite specific procedure, and should any condition of the test be changed the index figure would correspondingly change. It is an arbitrary rather than an absolute value. A similar situation exists with regard to viscosity of petroleum spray oil, where one also uses a definite standard method. The units are always given, for example, Saybolt universal, absolute, S.A.E., A.P.I., Redwood and Engler. When one states "70 viscosity Saybolt seconds oil at 100° F.," one is left in no doubt as to what "70" means, but clearly understands it refers to the Saybolt universal viscosity test. If it is clear that there is little or no distinction between the terms *unsulphonated* and "unsulphonatable," there should be no confusion. However, both refer to the same percentage figure; a regulation under California law requires that *unsulphonated residue* be given on the label for a petroleum spray oil; hence there does not seem to be justification for adoption of some other term for the test in California.

SUPERLATIVES.—Superlatives are equally undesirable as nicknames. Words such as "Concentrate," "Highly concentrated," "Extra strength," are usually not acceptable as part of a name of an economic poison. A product that is not concentrated cannot be so designated, otherwise it would be necessary to coin terms such as "Super-concentrated" to care for common concentrated solutions. To offer an economic poison for sale under a loose term or to employ such a term in discussion of it may confuse a user.

INVARIABILITY OF BRAND NAME PRODUCTS.—In the 1936 Annual Report of the State of California Department of Agriculture, Bureau of Chemistry, attention was called to the invariability of a brand name. A change of any kind in a brand name such as the change of a single letter or in the arrangement of words, makes a different brand name requiring separate registration. A short brand name is highly desirable and not a long one such as, "Global Combination Treatment Worm Capsules for Puppies and Dogs Weighing One to Ten Pounds," or "XYZ Special Solution No. 57 Moth Spray and Fumigant for Steam Laundries and Dry Cleaning Services." It was previously indicated that there is no place for nicknames in chemical names, and there is none in brand names, and their use generally leads only to confusion. To avoid this, manufacturers should particularly discourage use of nicknames for their products. However, we do permit on labels and advertising an abridged brand name if the brand name is used correctly the first time, and there is a clearly worded note to indicate any abbreviation that will be used later in its stead.

There was a case where a manufacturer had two plant sprays with closely similar names. One was a petroleum oil spray suitable for application to foliage and the other contained in addition a small percentage of a different ingredient that made it suitable only for dormant application to deciduous trees. A grower who had long used the first product with satisfaction erroneously purchased and applied on foliage the second one carrying the similar brand name and sold in a similar package. Severe damage resulted. Each product was so labeled as to comply with the requirement of law. Each material was clearly distinguished in the mind of the manufacturer by long familiarity with his products, but opportunity for confusion did exist in the mind of the consumer, and the manufacturer was at least morally remiss in not having adopted more clearly distinguishable brand names. Consistent use of the exact name for each product will minimize the danger of confusion between products of different manufacturers and between different products of the same manufacturer. If a brand name is brief, clearly discernible, and not confused with unrelated words and signs, the tendency to use a nickname for it is reduced.

Technical men and governmental agencies should be especially careful to refer to a product by an accurate descriptive name, whether it be the chemical name or a commercial name. Federal and other bid proposals should be specific and incapable of misinterpretation. In California manufacturers are required to maintain from year to year a uniform or improved composition or quality for each brand name product, and to indicate by at least an identifying change in name any variation made in the composition. Some leeway is given manufacturers when it is necessary to alter a composition due to priority rulings, allocations, and the like, in order for them to continue manufacturing at all. An experienced investigator stated to the writer that he worked for three years with a certain spreader with various results, and then found that the composition had been changed four times during the interim. There is no objection to change, per se, but California requires a distinguishing mark to identify each revised formula. When a brand name of an economic poisons product is mentioned, care should be taken always to use it identically as it has been registered. Technical men in general should try to give specific chemical names of any materials or mixtures used. When this is impossible, in their publications some investigators follow the practice of reporting proprietary materials by describing certain constants and footnoting the reference with a brand name so that exact compositions may be checked with the manufacturer. This seems a fairly safe rule to follow when it is necessary to work with proprietary products. Manufacturers of pest control materials should guarantee as the active ingredient or ingredients, the exact chemical, if known, and show its equivalent percentage in terms of chemical elements, if equivalents tend to simplify the guarantee.

CONCLUSION.—Technical language requires clear, precise, and adequate expression. Correct terminology for economic poisons is not only of importance to users and manufacturers to assure maximum results, but also an aid to entomologists, plant pathologists and chemists interested in advancing the knowledge of their work.—9-5-43.

A Report on the Penetration of Packaging Materials by Insects

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The importance of a thorough understanding of the biology and control of stored products insects in connection with the food situation in the war effort, with regard to the supplies for the armed forces and civilian population in our own country and those of our allies, has been evident for some time. However, the situation now has become critical for at least five distinct reasons: *viz.*, (1) the necessity for storing dried, dehydrated, and cured foods in great quantities for considerable periods of time: (2) the difficulty of obtaining suitable packaging materials that will endure rough handling and remain vapor tight, and also completely resist the attacks of insects;[2] (3) irregularities in cleaning and disinfecting storage warehouses and transportation facilities, particularly freight cars, barges, and cargo ships; (4) the hazards of insect infestation and contamination on shipboard during transit, which requires weeks and even months of temperature and moisture conditions extremely favorable to the development of insects; and (5) the tropical climates with their large numbers of insect pests which attack all kinds of edible products. Frequently these materials must be dumped in areas where exposure to high temperatures, and rain make them even more susceptible to infestation.

The recognition of these problems as vital to the success of the war effort resulted in the organization of a group in the Division of Entomology and Parasitology, University of California at Berkeley, to formulate a project covering the general scope indicated above.

Accordingly suitable quarters consisting of dark rooms and laboratory facilities for rearing stored food products insects, were set aside, and equipment, especially rearing containers and temperature and moisture control apparatus, was installed. Cultures of some 20 species of stored food insects were already available and formed a nucleus for the present investigation.

Early in 1942 new types of packaging materials designed for use as substitutes for metal containers were being tested at the U. S. Dept. of Agriculture, Western Regional Laboratory, Albany, California, and the problem of testing such materials for insect penetration and infestation was referred to our group. The work soon resolved itself into two main projects: (1) studies of the biologies and food habits of the insects, especially in relation to dehydrated products, and (2) the testing of packaging materials in relation to insect penetration, contamination, and infestation.

The work was further augmented by information obtained through participation in Regional Dehydration Training Schools conducted under the auspices of the Agricultural Research Administration, the Bureau of Agricultural Chemistry and Engineering, and the Agricultural Marketing Administration of the U. S. Department of Agriculture held at Albany, California, and Rochester, New York, in September and October, 1942. Requests for testing packaging materials have been received at a ever increasing rate, not only from the armed forces, but also from commercial manufacturers, distributors, and users of packaging materials.

Insect penetration of packaged foods is not a new problem but has been previously investigated, mostly with dried fruit, by several workers including Parker (1913, 1915) and Myers (1927). More recently Stracener (1938) has reported tests with multiwall, metal strip-sealed bags for milled rice and Hickin (1942) noted penetration of transparent cellulose film by *Ptinus*.

Method and Techniques.—In connection with the packaging experiments stock cultures of 32 species of stored product insects are maintained continuously. The insects are largely reared in gallon glass mayonnaise jars with muslin lids to allow relatively free passage of air. By varying the foods, humidities, and tem-

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[2] Infestation by insects is not necessarily the primary consideration since penetration without infestation may be equally serious in that it both destroys the moisture-proofness of the container and allows other organisms to enter.

peratures according to the requirements of the various species, large numbers of insects are available for biological studies and penetration tests. The major portion of the cultures are maintained in a room having a north exposure in a granite building. The temperature ranges from 67° F. to 83° F. and the relative humidity averages approximately 60 per cent. At the present time penetration studies are being conducted with approximately 15 species of insects. Although the rearing methods as regards moisture content, amount and kind of food, places for pupation, etc., vary somewhat with each species, the cadelle may be used as an example of our rearing methods.

Large numbers of adult beetles are introduced into 20-gallon ash cans half filled with rolled barley. The bottom two or three inches of food is dampened to the consistency of wet mash. Strips of cellocotton are placed in the culture for oviposition. From time to time these strips are transferred to other jars of moistened rolled barley. The larvae develop rapidly on this diet and large populations may be obtained in a short time. Rolled barley is apparently an adequate food and has the further advantage that larvae may be readily separated from it. Yeast and dried skim milk are sometimes added to supplement this diet. When adults are desired, strips of *Cellotex* or corrugated cardboard are placed in the culture to provide places for pupation.

Since preliminary tests showed that large larvae of the cadelle, *Tenebroides mauritanicus*, are more aggressive in entering packages than any of the other insects available, these were used as the test insect in most experiments. This species has long been known as a borer in wooden structures in granaries, storage bins, warehouses, and ships and is reported to penetrate various packaging materials such as sacks, parchment, cardboard, and even waxed and other papers (Back & Cotton 1926b). As is the case with most stored food pests populations are likely to reach high levels where there is a lack of sanitation. Under these conditions structures may be riddled by their boring.

Certain points may be kept in mind regarding materials to test for resistance to penetration by insects. It is highly desirable at the present time that results be of practical value and hence tests must be limited more or less closely to materials now in use or readily available in large quantities. Numerous factors doubtless influence the readiness of penetration, among which the following are certainly of importance: (a) nature of the material, *e.g.*, metallic, wooden, paper, synthetic; (b) thickness of the packaging material,—single or multiple layers, especially those built up from sheets of different materials; (c) effect of creases, folds, corners, scratches; (d) chemical treatment and addition of mechanical agents such as abrasive powders.

Materials to be tested are usually in the form of small packages (approximately 3×5.5 in.). Tests of these small packages are made in gallon jars. Ash cans are usually used for larger packages. In either case the bottom of the container is covered with a disk of *Kraft* paper to provide more secure footing for the insects. If contaminated conditions are to be simulated a small amount (10 to 50 grams depending on size of container) of whole wheat flour is sprinkled on the paper disk. This contamination provides the insects with food and a place to hide, and more closely simulates storage and warehouse conditions. Contamination is usually used with the various flour beetles and lepidopterous larvae. Small packages are either used in pairs or tested singly. In the latter event they are wrapped with a layer of *Kraft* paper held in place with a rubber band or heavy cord. Here again usual storaging and packaging conditions are simulated in order to give the insects more secure footing on the package. Flour is not placed directly on the package since it is possible that this might affect penetration of the packaging material. The number of insects utilized in each container depends on the species involved, other species which may be utilized in the same test, the developmental stage of the insect, the size of container, and the size of the package. Under most conditions of testing 10 cadelle larvae or 25 individuals of some other species were regarded as testing units for each gallon jar. The numbers utilized were thus relatively large to allow a reasonable chance of penetration in case of high mortality. However, since under storage conditions the number of larvae might be unlimited, a better procedure for the test would be to keep the population constant. This is now being

done in further tests not yet completed. Lower concentrations also are being used. Frequently combinations of insects were tried. Thus cadelle larvae and saw-toothed grain beetle adults were sometimes used together. Where the larvae of the insects were free-living usually both adults and larvae were utilized. In the case of moths, however, only larvae were introduced into the cultures. Packages up to 50 pounds net have been handled in large ash cans. Penetration tests were conducted in a room which was maintained at approximately 50 per cent relative humidity and 80 ° F.

Packages were given a preliminary examination at the end of two weeks. If they showed any external signs of penetration they were opened and examined from the inside. Containers such as the *Bemis* bag with several liners must be examined layer by layer. All surfaces were carefully examined and small holes detected by passing the material over a bright lamp or other suitable background. Scarification and penetrations were noted and classified according to position (top, bottom, side) and type (made in fold, crease, smooth area, seam, etc.). Finally the contents of the box were examined for insect infestation. Where possible replicates were made and the length of exposure varied from 2 weeks to 3 or more months.

In experiments with chemical repellents small packages, approximately 1×2×4 inches in size were made from paper towelling which was first dipped in a solution or a suspension of the desired chemical in a soft wax (No. 2305, Western Waxed Paper Co.) kept molten in a deep trough in a boiling water bath. The paper was then drawn through a simple press made of two pieces of quarter-inch glass tubing held in vertical slots about 6 inches apart and kept in rather close contact by a lead weight set in each slot. Live steam was passed through the tubes to keep them hot. The amount of wax solution left upon the paper varied but little as indicated by these indicated by these sample data:

Weight of paper towelling per sq. inch	Weight of paper plus wax and chemical per sq. inch	
	A[1]	B[1]
0.0361	0.1131	0.1207
0.0367	0.1091	0.1166
0.0367	0.1025	0.1187
Ave. 0.0365	Ave. 0.1116	Ave. 0.1187

[1] (A, upper part of sheet and B, lower part of sheet, as it came from the press.)

From these data it may be seen that the sheet as used in making the packages was by weight about one-third paper and two-thirds wax plus chemical. In order to make the bags of uniform size and shape they were formed about a wooden mold and all laps were sealed tightly by pressing with a warm soldering iron. The bags were filled loosely with flour and the upper ends were closed and sealed with special care. Two bags treated with the same chemical were laid on the side at the bottom of a gallon battery jar together with a few grams of loose flour and ten large cadelle larvae were added. Such a set up constituted a "unit test" which was kept in a small ventilated room at 30° C. and approximately 60 per cent relative humidity. The jars were shielded from strong light and were examined at intervals of a few days to note toxic effects and the time of first penetration of a bag.

Until recently all tests were made on prepared packages of various sizes but a method is now being developed for direct testing of films without the necessity of making them into packages. At present pint *Mason* jars with *Kerr* type lids are being utilized in these tests. A disk of the film to be tested, with or without a fold, is placed over the mouth of the jar. A ring made from one of the self-sealing lids is placed over the film thus exposing an "arena" 1.75 inch in diameter. A self-sealing lid is inverted over the above and the cap screwed down tightly giving the "arena" a depth of 0.19 inch. Three cadelle larvae in the ultimate or penultimate instar are placed in the "arena." Penetrations are readily observed as the larvae drop down into the empty jar. This type of testing unit is quickly made and may be effectively used in experiments on the effect of various foods on penetration, the comparisons of penetrating power of various insects, etc. A similar method has been used in the study of repellents. In this case the larvae was allowed to move away from the treated area. A sheet of paper towelling treated with wax only, and one treated with wax plus the desired chemical were fastened together with an interlocking lap sealed carefully and reinforced with fine wire staples. A half-inch fold was made in this composite sheet at right angles to the lap and in this folded condition the sheet was held on the lower end of a bottomless can (4 inches wide by

3 inches high) while the top was carefully forced part way on over the paper. Hence an "arena" of the same nature as that used by Wigglesworth (1941) in his work on the sensory reactions of the human louse was formed, half treated with the desired chemical and half free of it. The fold was not essential but it gave the insects a preferred place to penetrate the paper and hence shortened the time needed for a test. Five large cadelle larvae were placed in each of the cans which were kept in the room previously mentioned. Reactions of the larvae, *e.g.*, avoidance of the treated area, toxicity, and penetration of the paper were noted at daily intervals without disturbing them.

Materials tested: The following is a list of materials thus far tested:

1. Super calendered unbleached sulphite.
2. Laminated amber diaphane.
3. Kraft plus 3 per cent *Dowicide* (a chlorinated phenol derivative).
4. Double waxed parchment paper.
5. *du Pont Cellophane* 600.
6. *du Pont Cellophane* M.S.T. 300.
7. *Slyvania Cellophane* 300 tiplex.
8. *Thermophane A.* (a M.S.T. cellophane, moisture proof, heat sealing, transparent type of packaging material laminated to a sulphite paper.)
9. [1] *Reynolds Metal Bag (type A 10)* covering *Standard 17 DF Solid Fibre Case.* Composition of bag as follows: dense *Kraft*, asphaltic compound, solid sheet alloyed lead, moisture-proof adhesive, cellophane, special heat sealing coating.
10. [1] *Bemis* bag covering *Standard 17 DF Solid Fibre Case.* Composition of bag as follows: outer wall, 0.001 inch leadfoil laminated each side with 15 pounds asphalt to 30 pounds dense *Kraft;* center wall, 50 pounds dense *Kraft* waxed to 100 pounds; inner wall, 40 pound dense *Kraft;* closure, taped, sewed, and wax dipped.
11. [1] A fibre case double dipped in a thermoplastic wax (J-ration). First dip very hot for penetration. Second dip cool to wax outside and seal gaps.
12. [1] *Bates Multi-wall* paper bag (5 and 7 ply asphalt laminated bags).
13. Paper towelling treated with wax.
14. Abrasive paper, *Armour's No. 320A Crystolon.*

[1] These materials were tested as commercial packages weighing 12½ or 25 pounds.

All of the above materials were penetrated by one or more of the insects tested. In many of the tests the packages were penetrated with ease and usually within a relatively short period of time. In our tests, the thermoplastic product (No. 11) shows the most promise of being insect-proof.

With some of the insect species the presence of whole wheat flour on the floor of the test chamber appeared to make conditions more favorable for penetration. Evidence was also obtained which suggested that the contents of the package may influence insect penetration.

Several of the package materials would be more resistant to insect attack if it were not that in making them into containers, creases, folds, and roughened areas are formed. For some species, at least, these disturbed areas are favored points for penetration probably because they provide better footing and leverage as well as traction for the mandibles.

A great variation was observed in the ability of stored product insects to penetrate packaging materials. As would be expected those that have boring propensities are the best penetrators. Thus the cadelle larva, *Tenebroides mauritanicus*, was the most efficient of the insects tested in penetrating packages. The lesser grain borer adult, *Rhyzopertha dominica*, proved to be rather effective and even the granary weevil adult, *Sitophilis granarius*, demonstrated an ability to penetrate numerous package materials. The flour beetles *Tribolium* spp. and *Aphanotus destructor*, adults and larvae, and the moths *Ephestia* spp. and *Plodia interpunctella*, larvae, for the most part appeared to be poor penetrators and we have not yet been able to demonstrate that the saw-toothed grain beetle adult *Oryzaephilus surinamensis* is able to penetrate packages (cf. the contrary results of Back & Cotton, 1926a). Likewise, although the drug store beetle, *Stegobium paniceum*, adult, has distinct boring ability, it did not appear to be a good penetrator in any of our tests. Table 1 summarizes the results obtained from trials with seven different packaging materials and nine different insects. In this series of tests the

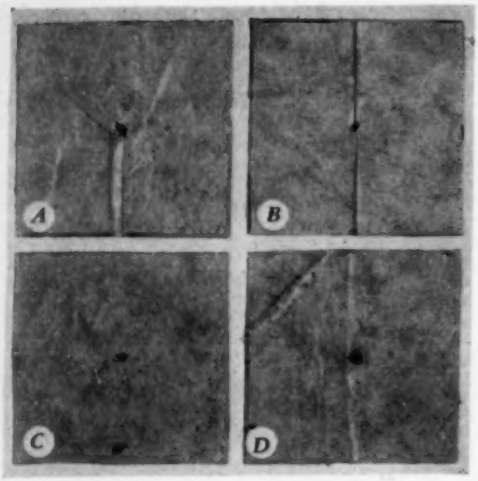

FIG. 1.—Penetrations by the larvae of the cadelle in Reynold's metal bags enclosing cartons of dried fruit. A, corner penetration; B, crease penetration; C, smooth surface penetration; D, fold penetration. ×0.63

cadelle larva penetrated all the packaging materials regardless of whether they contained white flour or dehydrated potatoes. The granary weevil adult seems to be nearly as efficient. It penetrated all of the package materials but in some cases it did not gain entry into the packages which contained dehydrated potatoes while in others it failed to penetrate the packages that contained white flour. The lesser grain borer adult and the broadhorn flour beetle adults and larvae are in the third position both having penetrated four of the materials. The lesser grain borer adult penetrated only packages that contained white flour. Of the remaining insects the saw-toothed grain beetle adult is the only one that failed to penetrate any of the offered materials.

Only the cadelle larva, the lesser grain borer adult, and the sawtoothed grain beetle adult were used in tests with the material known as *Thermophane A*. In limited tests of these insects the cadelle and the lesser grain borer were able to penetrate the material. This packaging material has shown some promise but further tests are necessary.

Many different trials were made with Reynolds metal or similar types of Kraft-asphalt-leadfoil laminated bags. This material offered little resistance to the cadelle larva. Many penetrations were made within a two-week period. The cadelle entered most freely through areas that had been roughened in making bags or wrappers although it would occasionally penetrate a smooth surface (Fig. 1).

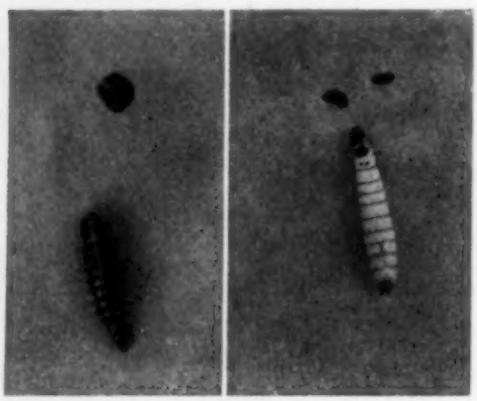

FIG. 2.—Insect penetrations in Reynold's metal packages containing dehydrated filet of sole. Right, the cadelle larva; left, the larva of the hide beetle. ×1.5

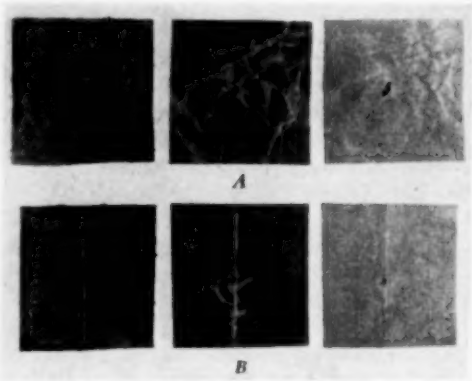

FIG. 3.—Penetrations by the cadelle in *Bemis* bags enclosing cartons of dried fruits. A, penetration at a corner through all three liners; B, penetration at a crease through all three liners. ×0.57

In one series of tests Reynolds metal packages containing dehydrated filet of sole were exposed to several kinds of insects. Of these the only two which were able to penetrate the packages were larvae of the cadelle and of the hide beetle, *Dermestes vulpinus* (Fig. 2).

In other tests with *Reynolds* metal containers several different species of insects were utilized together. In most cases, at least, one of these was able to penetrate the package. It was not possible, of course, to determine just which species made the penetrations and at this time we can state

only that there are other species besides the cadelle and *Dermestes* that can penetrate this material.

A considerable amount of work was done with *Bemis* bags. The cadelle had no difficulty in penetrating this material and the nature of its penetration is variously shown in figure 3. Other species of insects were used together and at least one of these was able to penetrate this package. However, if it were not for the fact that the cadelle penetrates this material course, in the presence of large populations damage may result even from such relatively innocuous insects.

The most satisfactory of the materials tested was a heavy cardboard container dipped in a thermoplastic material (No. 11). Of the 10 insects tested only the cadelle larva was able to successfully penetrate it and this in only one case and with considerable difficulty. Apparently the *Thermoplastic* dip along with the heavy cardboard offers resistance to insect attack. The greatest weakness of this type of package is the seal although it should be possible to improve this feature.

Table 1.—Results of an experiment to determine the ability of various insects to penetrate certain packaging materials.

PACKAGING MATERIAL	Super calendered unbleached sulphide		Laminated amber diaphane		*Kraft* 3 per cent *Dowicide*		Double waxed parchment		*du Pont Cellophane* 600		*du Pont Cellophane M.S.T. 300*		*Sylvania Cellophane 300 triplex*	
PACKAGE CONTENTS	flour	dehydrated potato	flour	dehydrated potato	flour	dehydrated potato	flour	dehydrated potato	flour	dehydrated potato	flour	dehydrated potato	flour	dehydrated potato
SPECIES														
Saw-toothed[1] grain beetle	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Confused[2] flour beetle	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Broadhorn[2] flour beetle	+	+	−	−	−	+	− − −	− − −	−	−	+	−	+	+
False black[3] flour beetle	−	−	+	−	−	−	−	−	−	−	−	−	−	−
Drugstore[1] beetle	+	+	−	?	−	−	−	+	−	−	−	−	−	−
Lesser grain[1] borer	+	−	+	−	−	−	+	−	−	−	+	−	−	−
Granary[1] weevil	+	−	+	−	+	−	+	−	−	+	−	+	−	+
Mediterranean[2] flour moth	+	−	−	−	−	−	−	−	−	−	+	−	−	+
Cadelle[3]	+	+	+	+	+	+	+	+	+	+	+	+	+	+

+ = penetrated
− = not penetrated

1 = adults
2 = adults and larvae
3 = larvae

The thickness of the packaging material is undoubtedly an important matter. Thus paper towelling, either plain or waxed, is penetrated by cadelle larvae in two to five days whereas they require several weeks in case of the heavy materials. For instance bags made of muslin heavily impregnated with wax were just penetrated after six weeks. The granary weevil adults can penetrate nearly all the thin preparations tested but none of the heavy ones. This situation probably prevails with all the flour beetles and moths which do not have strongly-developed boring habits. Of

An interesting point is the resistance offered by *Armour's No. 320A Crystalon Abrasive* paper which, tested with cadelle larvae by the small bag method, was penetrated only after nine months of continuous exposure. At the present time no penetration has resulted in a continuing arena test which has already lasted six weeks. If tests with other insects are equally encouraging the possibility of using such materials will be worth serious condideration.

The addition of chemicals to the con-

tainers of foodstuffs for the purpose of protecting them from insects is a procedure which may be of value in addition to ordinary sanitary and packaging precautions. Such chemicals may act as poisons or as repellents, or both, but if the invading insects are numerous a poison will be of little use since removal of a little of the container by each individual before it is killed will soon result in one or more holes through which other insects may enter. Consequently attention has been directed toward the discovery of repellents.

About 40 compounds have been tested in the wax-impregnated packages. For purposes of comparison the materials have been classified arbitrarily according to whether or not they prevent penetration for a 21-day period. Those so far studied which are effective for this period are:

Compounds	Concentration (Per Cent)	Time to First Penetration (Days)
benzyl disulfide	4	37 (6 larvae dead in 17 days)
thialdine	4	43 (8 larvae dead in 8 days)
p-tert-amyphenol	3	29 (9 larvae dead in 29 days)
rotenone	3	27 (8 larvae dead in 12 days)
o-dinitrobenzene	4	25
o-nitro diphenyl	3	22 (8 larvae dead in 8 days)
m-dinitrobenzene	4	21 (8 larvae dead in 21 days)
3,5 dinitrocresol	4	none (10 larvae dead in 5 days)
	2	none (10 larvae dead in 8 days)
	1	none (10 larvae dead in 9 days)

The high mortality caused by most of the compounds above undoubtedly prolonged the time until the first penetration.

Among the substances giving slight or inappreciable protection the following may be mentioned. The figures in parenthesis are concentrations in per cent and the materials are arranged according to general nature, e.g., all sulfur compounds are together but with no reference to order of efficiency:—

Sulfur (3), dry lime-sulfur (3), thiourea (3), o-ethyl *sym* methallyl xanthate (3), diamino diphenyl sulfide (3), tetramethyl thiuram disulfide (3), zinc dimethyl dithiocarbamate (4), lauryl thiocyanate (3), tert butyl thiocyanate (3), barium, lead, copper, and cerium naphthenates (3);
1,2,3, trichloro propane (3), 1,1,1,2,3, pentachloropropane (3); diamyl amine (3), chloramine B (Na benzene sulfon chloramine) (3).

A few of the materials listed above have been tested by the arena method with half the surface treated and the other half untreated. Results to date show that the treated side is not penetrated when the following materials are used at 1 per cent concentration in wax applied to paper towelling: 3,5 dinitro-o-cresol, 2 chloro, 6 phenyl phenol and 2,6 dimethyl naphthalene.

SUMMARY.—In order to provide insects for testing the resistance of packaging materials to the attack of stored products pests colonies of 32 species of these insects have been established. The general methods of rearing are discussed. Tests of resistance to penetration are carried on according to three techniques: (a) exposure of small packages or flat sheets of various packaging materials to one or several species, (b) similar exposure of commercial packages, (c) exposure of small bags or flat sheets of paper towelling impregnated with wax plus any desired chemical to test possible repellent effect.

On the basis of preliminary work it may be tentatively concluded:

1. With some insects penetrations of package materials permeable to odors is apparently favored by the presence of food.
2. Those insects with propensity for boring are apparently the best penetrators of packaging materials.
3. At least one stage of each of the common stored food pests, except the saw-toothed grain beetle, was able to penetrate some of the materials tested.
4. None of the commercially used metal-substitute packaging materials tested is strictly insect-proof. An abrasive paper is still under test.
5. The most promising type of material thus far tested was a heavy cardboard carton double-dipped in a thermoplastic material.
6. Among the more promising transparent cellulose materials are such products as *Thermophane* A and *Cellophane* 600. However, these materials are only relatively more resistant to penetration than most light weight materials tested.
7. Laminated *Kraft*-asphalt-leadfoil-cellophane bags showed little resistance to insect penetration.
8. Among the multiwall bags the *Bemis* bag was the most promising. However, it was readily penetrated by the cadelle.

9. Manufacturing techniques are needed which will produce uniform containers without roughened spots, creases, folds, and similar areas where insects penetrate most easily.
10. Repellents offer a possible solution to the problem of keeping insects out of packaged food. Toxicity is shown by many compounds, especially phenol derivatives, and the effects due to repellency are thereby obscured.—7-20-43.

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A Report on Insect Infestation of Stored Grain in California

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The following report is based upon a survey of approximately one hundred and twenty-eight infested granaries[1] in ninety-seven localities of California. This number represents about 75 per cent of the granaries actually examined. The remaining 25 per cent were found to be uninfested, although a great many of these were new construction and freedom from insect infestation was therefore probably due to this fact and not to sanitary practices. However, where sanitary practices had been strictly followed little or no infestation was found about granaries of several years standing.

The localities surveyed (Fig. 1) have been roughly grouped into four main areas on the basis of differing environmental conditions. These are the Sacramento Valley, the San Joaquin Valley, the Coastal area from Monterey Bay south to Los Angeles County, and the southern interior of Los Angeles, Riverside, and Imperial Counties.

Sacramento Valley. Mackie & Carter (1937) reported a survey of granaries in the Sacramento Valley in 1933 which revealed that the four primary pests of stored grain were present in the following order of abundance: (1) the granary weevil, *Sitophilus granarius* (Linn.). (2) the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), (3) the rice weevil, *Sitophilus oryza* (Linn.) and (4) the lesser grain borer, *Rhyzopertha dominica* (Fab.) The results of our survey of this area agree with the report of Mackie and Carter, although at the present time the lesser grain borer seems to be on the increase and may eventually surpass the rice weevil in importance.

San Joaquin Valley. In this region the rice weevil assumes more importance and in the southern portion of the area it is

[1] For comparable warehouse surveys, see Mackie & Carter (1937: 276) and Doane (1918: 313).

more destructive than the granary weevil. The lesser grain borer and Angoumois grain moth were found sparingly, although near Merced two bins of barley were found which had been nearly destroyed by the former.

Coastal Area. In the coastal counties the granary weevil was fairly abundant, the rice weevil rarely important. The Angoumois grain moth was scarce and the lesser grain borer was not encountered.

FIG. 1.—Location of infested granaries surveyed. Enclosed areas indicate Sacramento Valley, San Joaquin Valley, Coastal Region and Southern Interior areas respectively.

Southern Interior Area. In this region the rice weevil is of primary importance and in Imperial County it replaced the granary weevil in all of the granaries examined. This latter county also appeared to be well infested with the less grain borer. The Angoumois grain moth was common.

PRIMARY GRAIN PESTS.—In this group we have placed the species which attack whole grain at normal moisture contents prevailing in storage. Considering the state as a whole, the granary weevil must be regarded as the most important pest of whole grain. It was present in 60 per cent of the infested granaries encountered. However, its relative importance diminishes as one progresses southward and that of the rice weevil increases (Table 1). In Imperial County the latter displaces the former. The Angoumois grain moth and lesser grain borer are most important in the Sacramento Valley and southern interior area. In the San Joaquin Valley they are local in occurrence and along the coast the lesser grain borer appears to be absent. However, it has only been known from California since 1933. (Mackie and Carter 1937). In no case was the Angoumois grain moth found in destructive numbers. Apparently serious damage is limited to grain where harvest is long delayed.

Table 1.—Comparison of the frequency of occurrence of granary insects in the major California grain storage areas. The ratios indicate number of granaries in which the species were present in relation to number of infested granaries examined.

SPECIES	SACRAMENTO VALLEY	SAN JOAQUIN VALLEY	COAST	SOUTHERN INTERIOR
Primary				
Sitophilus granarius	31:42	15:37	18:33	3:16
Sitophilus oryza	6:42	16:37	7:33	10:16
Rhyzopertha dominica	2:42	3:37		3:16
Sitotroga cerealella	11:42	2:37	2:33	6:16
Secondary				
Oryzaephilus surinamensis	28:42	19:37	14:33	8:16
Oryzaephilus mercator		6:37	3:33	3:16
Tenebroides mauritanicus	10:42	11:37	3:33	3:16
Tribolium confusum	30:42	13:37	15:33	12:16
Tribolium castaneum	2:42	14:37	5:33	9:16
Laemophloeus pusillus	12:42	10:37	3:33	3:16
Laemophloeus ferrugineus	3:42	9:37	7:33	5:16
Ephestia kühniella	9:42	2:37	5:33	
Plodia interpunctella	4:42	2:37	2:33	
Aphomia gularis				1:16
Corcyra cephalonica				1:16
Minor or Incidental				
Attagenus piceus	1:42	2:37	2:33	
Perimegatoma variegatum	1:42	2:37	3:33	
Trogoderma versicolor		5:37	3:33	2:16
Trogoderma sternalis		2:37	1:33	
Anthrenus verbasci		2:37	2:33	
Cathartus quadricollis	4:42		2:33	
Ahasverus advena	10:42	7:37	10:33	1:16
Aglenus brunneus			1:33	
Typhaea stercorea	10:42	1:37	5:33	1:
Cryptophagus inscitus		1:37	2:33	
Cryptophagus cellaris		1:37	1:33	16
Cryptophagus sp.	4:42			
Henoticus californicus	1:42	2:37	1:33	
Enicmus minutus	4:42	1:37	1:33	
Enicmus crenatus			1:33	
Cartodere filum			1:33	
Melanophthalma americanum	1:42	1:37	1:33	
Alphitophagus bifasciatus	3:42	3:37	4:33	
Gnathocerus cornutus			2:33	1:16
Palorus ratzeburgi	1:42	2:37		1:16
Alphitobius diaperinus		1:37	3:33	2:16
Alphitobius piceus	4:42	2:37		1:16
Tenebrio molitor	1:42			
Tenebrio obscurus	7:42	3:37	2:33	
Ptinus hirtellus	1:42		4:33	2:16
Ptinus tectus			2:33	
Ptinus gandolphei	1:42	1:37		
Trichogenius globulus			1:33	1:16
Carpophilus dimidiatus		3:37		
Haptoncus luteolus	1:42			
Pyralis farinalis	9:42	2:37	2:33	3:16
Hoffmanophila pseudospretella	1:42		1:33	1:16
Endrosis lacteela			1:33	
Paraneura simulella			1:33	
Scenopinus fenestralis	2:42		2:33	
Lepinotus patruelis			2:33	
Liposcelis divinitorius	1:42	1:37	2:33	

SECONDARY PESTS.—In this category we have placed the common grain feeding insects which frequent granaries but rarely attack whole grain at the moisture content which prevails in normal storage. Most of these are associated with the primary pests and follow closely upon their attack.

The commonest and most ubiquitous of the secondary pests are the confused flour beetle, *Tribolium confusum* J. duV. and the saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linn). Both were more or less equally common throughout the state, and frequently were the only pests encountered. To the southward the confused flour beetle encounters more and more competition from the rust-red flour beetle, *Tribolium castaneum* (Herbst). However, the latter does not replace the former in the southernmost part of the state as the rice weevil does the granary weevil, and the two exist together in the same granaries.

The flat grain beetles (*Laemophloeus* spp.) are encountered only a little less frequently than the flour beetles and saw-toothed grain beetle. In general they appear to parallel the flour beetles in distribution, the flat grain beetle, *L. pusillus* (Schön), roughly coinciding with the rust-red flour beetle, the rust-red grain beetle, *L. ferrugineus* (Stephens), with the confused flour beetle.

The moths were probably not adequately sampled. However, it appeared that the Mediterranean flour moth, *Ephestia kühniella* Zeller and the Indian meal moth, *Plodia interpunctella* (Hbn.) were fairly common granary insects, although in the Sacramento Valley, some of the records probably apply to the cacao moth, *Ephestia elutella* Zeller. None of these moths appeared to be very destructive although *Ephestia* spp. were rather commonly found breeding on the surface of bulk stored grain. These moths were encountered less frequently in the southern interior region, although the rice storage moth, *Aphomia gularis* Zeller and the rice moth *Corcyra cephalonica* Stainton were found only in that area.

MINOR AND INCIDENTAL SPECIES.—Thirty-seven species of minor or incidental granary insects were encountered. Most of these were abundant only where grain was out of condition. Locally *Trogoderma versicolor* (Creutzer) and *Attagenus piceus* (Olivier) may have been responsible for some slight damage but the remainder of the species are probably to be regarded as indicators of unsanitary conditions rather than as pests.

CONCLUSIONS.—(1) There are four main insect pests of stored whole grain in California, the granary weevil, the rice weevil the Angoumois grain moth, and the lesser grain borer. The first is the most important species in northern California, the second in southern California.

(2) Among the secondary species, the saw-toothed grain beetle, confused flour beetle, and rust-red beetle are common and almost equally widespread. The rust-red flour beetle and flat grain beetle become more abundant from north to south.

(3) Many minor or incidental species are associated with grain in the state. The majority of these are indicators of unsanitary conditions or that the grain is out of condition.—7-6-43.

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Forecasting Outbreaks of the Pea Aphid on Fall-sown Annual Legumes in the Pacific Northwest

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It has been observed in the Pacific Northwest that following mild winters widespread outbreaks of the pea aphid, *Macrosiphum pisi* (Kalt.), occur on fall-sown annual legumes, Austrian winter field peas, and the vetches. These legumes produce seeds for the wintercover crops which are profitable for the Pacific Northwest and are also important to the agriculture of the Southeastern States. More or less detailed observations on the pea aphid on these crops and pertinent weather data are available for a period of 26 years at Forest Grove, in western Oregon, and afford some basis for forecasting such aphid outbreaks. The anticipation of aphid outbreaks several months in advance would enable those interested in these crops to make appropriate plans.

It should be stated at once that these data do not apply to forecasting of aphid outbreaks on spring-sown peas or on alfalfa. It is probable that garden peas seeded in January or February in western Oregon and western Washington will escape serious aphid damage in years when no extensive infestation of fall-sown legumes occurs, but peas sown later may develop damaging aphid populations in any year.[2] Outbreaks on alfalfa may develop from overwintering eggs of *Macrosiphum pisi* regardless of winter temperature, as will be shown hereafter.

Our records indicate that the minimum temperature for the winter is the principal factor determining abundance of aphids in the spring on fall-sown annual legumes, although temperature in the fall, precipitation at critical periods, and the availability of suitable host plants early in the fall are other factors of some importance. The availability of suitable fall host plants is indirectly related to weather conditions, especially to late summer precipitation, and is directly related to farm practice. This factor is controllable, and, as was shown in a previous article (Rockwood & Reeher 1942), late fall seeding of annual legumes and elimination of volunteer annual legumes will greatly reduce spring damage by aphids to fall-sown annual legumes, even when winter conditions have been favorable to an aphid outbreak.

The importance of these factors in western Oregon is due to the fact that spring outbreaks of the pea aphid on fall-sown annual legumes arise from parthenogenetic forms of *Macrosiphum pisi* that overwinter on them. Pea aphids that move from alfalfa or Scotch broom as winged forms in the spring have not been factors of importance in such outbreaks.

Alfalfa is important as a host plant of *Macrosiphum pisi* during the usually dry months of July and August, when annual legumes are not available in quantity, and as a source of winged aphids to infest fall-sown annual legumes in the fall. It also may be an important source of aphids to infest spring-sown annual legumes in some years, especially in eastern Oregon and eastern Washington.

Red clover, which develops considerable populations of *Macrosiphum pisi* in this region only in the latter part of the spring, has not proved to be an important host in relation to aphid outbreaks on fall-sown annual legumes. Movement of winged *M. pisi* from scotch broom is probably an important factor in outbreaks on spring-sown garden peas in the sea-coast area of the Pacific Northwest.

Minimum Temperature.—No extensive outbreaks of the pea aphid have occurred on fall-sown annual legumes in the last 26 years in Washington County, Ore., following any winter when the minimum temperature registered 14 ° F. or below in a standard weather-instrument shelter at Forest Grove. Moderate outbreaks have occurred when the minimum was 18°; hence the critical minimum temperature is between 14° and 18° and the assumption appears to be warranted that it is approximately 15°. The length of the period of cold weather may also be important, as there is evidence that some

[1] The writers are indebted to the following former associates whose unpublished notes have been used: Mrs. S. K. Zimmerman (née Sadie E. Keen), T. R. Chamberlin, Cecil W. Creel, A. C. Burrill, F. R. Cole, and Merton C. Lane.

[2] No work was done on garden peas. The above statement was derived from general knowledge of local conditions over a period of years, acquired by experience and in some instances from other entomologists and growers.

aphids can withstand considerably lower temperatures for brief periods. Mean temperature, discussed below, would be indicative of the length of the cold period. Table 1 gives temperature records for 26 years at Forest Grove for the period September to June of each crop year.

the humidity and with the condition of individual aphids. The effect of low temperatures on aphids has been studied in detail by Wadley (1931), using *Toxoptera graminum* (Rond.). His experiments indicated that the probable low lethal temperature under controlled conditions is 10° F.

Table 1.—Mean temperature for coldest months, minimum temperature for crop year (September–June) and snow cover at time of minimum temperature at Forest Grove, Ore., 1916–42.

Year	Low Monthly Mean	Month	Minimum for Period	Date	Snow Cover *Inches*
1916–17	36.4 °*F.*	Dec.	9 °*F.*	12/29	3.2
[1]1917–18	39.7	Feb.	21	1/31	0
1918–19	39.7	Dec.	18	1/1	0
1919–20	30.6	Dec.	−15	12/12 and 12/13	15.5
[1]1920–21	39.7	Jan.	23	1/11	0
1921–22	33.6	Jan.	12	1/18	T
1922–23	34.6	Dec.	7	12/15	4.1
1923–24	36.0	Jan.	4	1/1	1.0
1924–25	32.8	Dec.	3	12/18 and 12/19	T
[1]1925–26	38.8	Jan.	21	1/13	0
1926–27	37.3	Jan.	3	1/21 and 1/22	5.2
1927–28	35.6	Dec.	14	12/31 and 1/1	2.5 and 4.3
1928–29	32.5	Feb.	4	2/7	4.2
1929–30	24.6	Jan.	−8	1/21	15.0
[1]1930–31	37.4	Dec.	19	12/30	0
1931–32	36.7	Jan.	13	2/2	T
1932–33	34.4	Dec.	5	12/9 and 12/11	0
[1]1933–34	43.4	Nov.	25	11/18	0
1934–35	37.2	Jan.	12	1/20	7.9
1935–36	33.1	Feb.	14	11/3 and 2/8	0
1936–37	27.7	Jan.	0	1/12	4.1
[1]1937–38	38.8	Jan.	24	12/8, 1/6 and 1/7	0
[1]1938–39	38.2	Feb.	18	12/13	0
[1]1939–40	39.8	Jan.	24	12/24 and 12/25	0
[1]1940–41	41.3	Jan.	18	12/14 and 12/15	0
1941–42	34.0	Jan.	13	1/5	T

Mean low monthly mean for 26 years = 35.9° ± 0.8°.
Median low monthly mean for 26 years = 36.6°.
Mean low monthly mean for all non-aphid years = 33.9° ± 0.9.
Mean low monthly mean for all aphid years = 39.7 ± 0.6.
Mean minimum temperature for 26 years = 11.6° ± 2°.
Median minimum teperature for 26 years = 13°.
[1]Aphid years (widespread outbreak on fall-sown annual legumes).

It is possible that the protection available to the aphids in the fields, either from vegetation or from snow cover, may be a concomitant factor that should be considered, but there has been little indication in our records that this need be done. Protection would tend to be a local factor and might account for abundance in certain fields in years when there is no general aphid outbreak.[1]

The actual lethal low temperature, inducing 100 per cent mortality of viviparous *Macrosiphum pisi* in the field, would be difficult to determine. It may vary with

or lower. The critical temperature, at which a majority of the aphids were killed in 10 hours, appeared to be 15°. He noted that aphids failed to survive low temperatures, even with means well above 32°, when such temperatures were prolonged. He also noted that small nymphs varied more in susceptibility to cold than did the other stages. Our field observations on *M. pisi* agree in general with his findings. Thus in the period January 6–12, 1922, Sadie E. Keen noted a considerable survival of all stages of *M. pisi* on vetch cover crops after a minimum of 17° on December 25, 1921, at Forest Grove. By January 20, following a minimum of 12° on January 18, no aphids were found. A later examination on February 4 showed many

[1] An outbreak is interpreted to mean the occurrence of countless millions of aphids and observable aphid damage in many fields. There are always some aphids on these crops and they are sometimes abundant enough to cause damage locally, but the term "outbreak" refers to damaging numbers over a wide area.

dead mature wingless parthenogenetic females on the ground under the plants and a few living forms, mostly immature, on the plants. Aphids were subsequently scarce all through the spring on fall-sown annual legumes. On February 17, 1923, Miss Keen noted that many of the first-stage stem mothers on scotch broom had been killed by a minimum of 15°. However, in December 1932 the senior writer noted that a small percentage of *M. pisi* (20 per cent), on the ground and in cracks under vetch, survived a minimum temperature of 5° without snow cover, although the host plants were killed. The low temperature had been accompanied by a drying east wind which blew day and night, drying up the plants and knocking the aphids to the ground. In this case, the highest percentage (30 per cent) of survival, as indicated by movement after 4 days in an unheated room, was among immature forms and only 7 to 8 per cent of the mature wingless parthenogenetic females recovered. Subsequently pea aphids were scarce on all crops in the spring of 1933 in the Willamette Valley. These observations indicate that to prevent spring outbreaks low temperatures do not need to wipe out the aphid population but only to reduce it greatly.

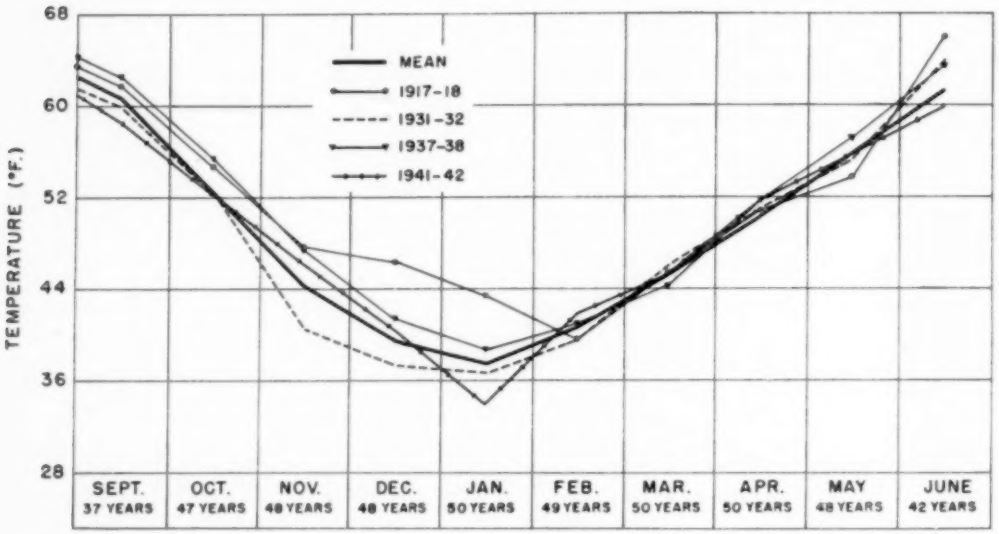

FIG. 1.—Monthly mean temperature curves. Forest Grove. Oregon. Aphid years; 1917–19, 1937–38. Non-aphid years: 1931–32, 1941–42

MEAN TEMPERATURE.—It would be desirable to base forecasts of aphid outbreaks on mean temperatures because they are indicative of the length of the cold period. The mean temperatures for 7- or 8-day periods (4 periods to each month) and the precipitation have been diagrammed for each month, September to June, inclusive, for each of 26 years at Forest Grove. A study of all our graphs indicates that no extensive pea aphid outbreak has occurred in the spring on fall-sown annual legumes in years when the mean temperature of any 7- to 8-day period during the preceding winter reached or went below 32° F., except for the crop year 1930–31 (31.8° mean in the last 8 days of December, with a minimum of 19°). It therefore seems safe to assume that if the mean temperature for a quarter of a month goes down to or below 31° there will be no extensive outbreak on fall-sown annual legumes the following spring.

Figure 1 represents the monthly mean temperatures for the crop years 1917–18, 1931–32, 1937–38 and 1941–42, and the average mean temperatures for as far back as there are United States Weather Bureau records (37 to 50 years). The years 1917–18 and 1937–38 were years of serious aphid outbreaks, but 1931–32 and 1941–42 were not. The graphs for 1931–32 and 1937–38 were selected because the deviations from the average of the means are less than for other years and the

curves fairly smooth. Some of the curves for other years are quite eccentric, both above and below the curve of average means, as is indicated by the curve for 1917–18. The graph for 1941–42 was selected because it shows only one important period of subnormal temperatures. The plus departures of the curves from the curve of average means for the two aphid years are noticeable and these plus departures are consistent for all aphid years of record. The most significant plus departures, when all aphid years are considered, appeared to be in the winter months December and January. which are normally the coldest months, The minus departures of the curves of the means for the non-aphid years of 1931–32 and 1941–42 from the curve of average means are also noticeable in the winter.[1]

A study of all our records (Table 1) indicates that the lowest monthly mean temperature in an aphid year was 37.4° F. (1930–31) and the highest low monthly mean temperature in a nonaphid year was 39.7° in 1918–19, although the mean temperature for the first week of January 1919 was 30.5°. However, 1918–19 appears to have been exceptional in respect to the lowest monthly mean temperature for a non-aphid year, as the next highest low monthly mean for a non-aphid year was 37.3° in 1926–27. The critical monthly mean is probably near 37°. The average monthly mean temperature for January (the coldest month) in 50 years' records is now 37.4°. The average lowest monthly mean for the 26-year period (1916–42) under consideration was $35.9° \pm 0.8$, which would be definitely below the critical mean. The average of the lowest monthly means in the total of 9 non-aphid years (with 7 years with lowest means and 1918–19 omitted, hence with the weight on the plus side) was $35.8° \pm 0.4$, and the average of the lowest monthly means in all 9 aphid years was $39.7° \pm 0.6$. The difference, $3.9° \pm 0.7$, is highly significant. The average for the aphid years, $39.7° \pm 0.6$, is also significantly higher, $3.8° \pm 1$, than the average for the lowest monthly means for the last 26 years and 2.3° above the normal mean of January for 50 years.

The average annual minimum temperature in the 26-year period was 11.6° F. ± 2, which is below the minimum (15°) limiting spring outbreaks of aphids on fall-sown annual legumes. Hence it would appear that aphid outbreaks in this area would probably not be very frequent.

DISCUSSION.—Before the crop year 1938–39 there had been no two consecutive years of general aphid outbreaks on fall-sown annual legumes during the period of our observations, and the aphid years were spaced 3 to 5 years apart. However, in the period 1937–41 there were four consecutive years of general pea aphid outbreaks, of which the crop years 1937–38 and 1939–40 had the largest, most damaging aphid populations. The minimum temperature for each of these two crop years was 24° F.; the minimum for each of the other two years was 18°, conforming to our assumption that a minimum temperature of 15° or above is required for an aphid year, an assumption borne out by all the previous years, both aphid and non-aphid, except the unusual non-aphid year of 1918–19, when the minimum temperature was 18°, and this crop year is covered by the quarter month mean temperature assumption (31°), as the mean for the first week of January was 30.5°. It is apparent that this period of four successive years of aphid abundance was very exceptional.

Statistical analyses of the differences in mean temperature between the totals of nine aphid and nine non-aphid years (selected as noted above) for each month showed that the difference (−0.5° for aphid years) in November was not significant; the difference for December and January (+4.1° for aphid years) was highly significant; and the difference for February (+2.2° for aphid years) was not significant.

Similar analyses of differences in average monthly precipitation between all non-aphid years and all aphid years showed no statistical significance for any month except April, when the difference (−1.27 inches for the aphid years) was significant at the 5-per cent level. That subnormal precipitation in the spring months favors aphid increase in western Oregon was noted during our observations, especially in April, May, and June of 1918, when the deficiency of precipitation, as compared with the normal of 1941, was −3.52 inches for the 3 months; and in the same months of 1938, when the deficiency was −3.97 inches.

[1] This discussion of the curves of mean temperature refers to graphs, not to the statistical analyses.

It was observed during our investigations that supernormal temperatures in October and November, especially if preceded by sufficient precipitation to produce abundant volunteer annual legumes and to stimulate early seeding of annual legumes, are conducive to large fall populations of *Macrosiphum pisi*, usually sufficient to damage early fall-sown annual legumes before winter. However, in every case where such large populations occurred and the temperature fell to 14° F. or below during the subsequent winter (as was noted especially in the crop years 1921–22, 1922–23, 1926–27, 1929–30, and 1932–33), no extensive spring outbreak has occurred in fall-sown annual legumes during the following spring. It has also been observed that precipitation at critical periods in March and April of aphid years has stimulated the aphid fungous disease (usually the fungus *Entomophthora aphidis* Hoffman predominated), which checked outbreaks of *M. pisi* at a point where the host plants were able to recover from aphid injury with but little loss to the crops. This was notably the case in the crop year 1933–34, when a very severe early aphid outbreak was checked by fungous disease about April 1. But in 1933–34 there would have been no spring aphid outbreak if the winter temperature had been low enough. Hence, precipitation is not a factor in so far as forecasting spring aphid outbreaks on fall-sown annual legumes in western Oregon is concerned, although it is a very important factor in determining the extent of aphid damage in an aphid year.

We have made few observations on pea aphid abundance in alfalfa and sweetclover east of the Cascade Mountains, and the data given above are not generally applicable to that region. We do know, however, that outbreaks of aphids on alfalfa occurred in that region in the crop years 1917–18 and 1927–28 and aphid damage to peas was reported to have been severe in 1933–34. The United States Weather Bureau records for 1917–18 at Milton, Ore., near the affected area, showed a considerable plus departure from the normal mean temperature in October, November, December, and January, with the lowest mean (37.5° F.) in February. Similarly, there were remarkably high plus deviations from the average of the means for November, December, January, and February in the season 1933–34, with the lowest mean (42.9°) in November. On the other hand, the season of 1927–28, in which an aphid outbreak occurred on alfalfa, showed strong minus departures from the average of the means for December and January, with the lowest mean (29.3°) in January. The season 1927–28 was not a year of general aphid abundance on fall-sown annual legumes in western Oregon. However, in the case of alfalfa east of the Cascade Mountains, the factor of fall oviposition of *Macrosiphum pisi* must be taken into consideration. At Milton in 1927 the precipitation for September was much above normal and that for October and November was also above normal. This would be conducive to a late succulent growth in alfalfa fields, whether irrigated or not, provided temperatures were high enough to prevent severe killing back of the alfalfa by freezing. The monthly mean temperature at Milton for October 1927 was nearly normal but with no frost, and that for November was 5.6° above normal with no frosts severe enough to kill back alfalfa (minimum 28° on November 1). Hence large fall populations of *M. pisi* could have developed and deposited large numbers of eggs from about October 15 through November, which is the usual oviposition period in the Pacific Northwest.

Our observations in alfalfa fields in this area in the fall and spring during the period 1935 to 1938, inclusive, indicate that the aphid population on alfalfa in spring bears a direct relation to the fall aphid population, which in turn is in direct relation to the condition of the alfalfa late in October. Hence, these factors—a warm fall preceded by supernormal precipitation in September—should be considered in determining bases for forecasting aphid abundance in an area where there is a considerable acreage of alfalfa.

The data accumulated during the years 1916 to 1942, inclusive, show that the following conditions are favorable to a severe outbreak of *Macrosiphum pisi* on fall-sown annual legumes in western Oregon: Greater than normal precipitation in September; above-normal temperature in October or November, and especially in December and January; and sub-normal precipitation in March, April and May.

Even though our data on outbreaks of *Macrosiphum pisi* east of the Cascade

Mountains are less adequate for forming such definite conclusions as have been drawn from those available for western Oregon, we would venture the following opinion as to conditions likely to induce outbreaks on alfalfa in eastern Oregon and eastern Washington: Precipitation considerably above normal in September, or late irrigation; and October and most of November without severe frost. Outbreaks are also likely to arise east of the Cascade Mountains on both alfalfa and peas, when the winter conditions are such (monthly means above 37° F.) as to permit survival of viviparous forms such as often occurs in western Oregon.

SUMMARY.—A study of weather records and field notes on *Macrosiphum pisi* on fall-sown annual legumes in western Oregon covering a 26-year period shows temperature in the winter months to be a basis for forecasting widespread aphid outbreaks on these crops.

Aphid outbreaks have not occurred when the minimum temperature for the winter fell below 15°. On the basis of mean temperatures for quarter months, such an outbreak has not occurred when the mean temperature for any 7- to 8-day period was 31° or below. On the basis of monthly mean temperatures, an aphid outbreak has not occurred when the lowest monthly mean temperature was 37° or below.

The presence of suitable host plants early in the fall and precipitation in September and in critical periods in the spring are factors having considerable effect on aphid populations but are secondary to the factor of winter temperature. Above-normal precipitation in September and no killing frosts in October and most of November should be taken into consideration in eastern Oregon and Washington, where there is much alfalfa.—7-19-43.

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The Western Spotted Cucumber Beetle as a Pest of Forage Crops in the Pacific Northwest

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The laboratory for the investigation of insects affecting cereal and forage crops, at Forest Grove, Ore., has accumulated many notes on *Diabrotica 11-punctata* (Mann.) (*D. soror* Lec.) over a period of 26 years. In view of the fact that considerable worth while information has been gathered, it seems desirable to make this available to other workers.

This species is not specialized in its feeding habits, either in the adult or larval stages. For this reason, it is probably one of the most difficult of Pacific Coast pests to deal with.

DAMAGE TO FORAGE CROPS.—Probably the most serious damage to forage crops is that caused by the feeding of the overwintered beetles on seedling clover just after the young plants have emerged from the ground. Whole fields seeded to red clover have been destroyed in March and early in April in all parts of the Willamette Valley in several years. Undoubtedly this pest is an important factor in causing unsatisfactory stands even where the seeding is not entirely lost.

In feeding on red clover seedlings the beetles of this species of *Diabrotica* seem to prefer the cotyledons. One or both cotyledons and the plumule may be consumed. Frequently in badly damaged fields only the bare stems are left and often these are eaten level with the ground. In 1938 this injury was simulated on potted seedlings by amputations with scissors. It was found that the loss of one cotyledon had very little if any effect on the seedling; the loss of both cotyledons stunted the plants and reduced the weight

[1] The writers are indebted to the following former associates, whose unpublished notes have been used: Cecil W. Creel, A. C. Burrill, Max M. Reeher, Mrs. S. K. Zimmerman (nee Sadie E. Keen), and A. E. Bonn. They also wish to thank J. C. Chamberlin, of the Division of Truck Crop Insect Investigations, Bureau of Entomology and Plant Quarantine, for permission to refer to unpublished data secured in 1941 at Forest Grove, Ore.

of subsequently well established young plants (87 days after seeding) by 33 per cent, as did also the loss of one cotyledon and the plumule. The loss of both cotyledons and the plumule caused the death of 80 per cent of the plants and reduced the weight of the survivors about 60 per cent as compared with undamaged checks. Seedling red clover plants without cotyledons and with but one tiny trifoliate leaf are commonly seen in the fields and may be caused by this injury. It is probable that such seriously damaged seedlings would never make satisfactory plants. When beetles were caged over a thick stand of red clover seedlings, the seedlings were all killed in a few days. Red clover blossoms are damaged in July by the new-generation beetles.

The larvae of this *Diabrotica* have occasionally greatly damaged or destroyed seedings of alfalfa in May in western Oregon and western Washington. In all such cases that have come to the writers' attention the alfalfa was seeded in May on land not plowed or otherwise prepared until April or later. Alfalfa seeded in June on land that was well prepared in early spring was not damaged.

Corn in various localities has occasionally been damaged by the larvae but not very seriously. Here, too, the time of preparation of the ground and seeding appears to be important, as the most seriously damaged corn is that which is earliest seeded. This was especially evident in a field on Tualatin bottom lands near Forest Grove, Ore., in 1932. In this case a small part of the field had been seeded earlier than the remainder, and this part was damaged an estimated 50 per cent whereas the damage to the later sown part was negligible. The silk and pollen of corn are damaged by the new-generation adults.

LIFE HISTORY, SEASONAL HISTORY, AND HABITS.—The beetles are active enough to move about at temperatures near 50° F. and show no definite inclination to hibernate in the usual sense of the term. They seek shelter late in the fall, however, and often congregate at that time in certain definite spots which are termed "caches," or "hibernation caches." These caches bear some resemblance to the hibernation caches of some of the coccinellid beetles, especially those of the genus *Hippodamia*, but the habit of congregating in winter quarters appears to be not so well developed in the case of *Diabrotica* beetles as with those of *Hippodamia*. The writers have found a very few caches of *D. 11-punctata* beetles on south or southwest slopes near water, seepage spots, or swampy places, near Forest Grove and near Rickreall in Oregon. Branigan (1915) recorded that he had found *D. soror* beetles in the winter in great numbers in "dry weeds along a levee" in Yolo County, Calif. Hence this habit also develops in a warmer climate than that of the Pacific Northwest. However, scattered beetles are often found in the fields all through the winter.

Dissections of beetles from hibernation caches in Oregon showed that 90 per cent or more of them were females and that most of these females had been fertilized prior to entering the cache, as the spermatheca contained spermatozoa or the bursa copulatrix contained sperm.

After the winter has passed (sometimes as early as January or February), the beetles become active at temperatures near 50° F. but probably do not migrate by flight until the temperature approaches 60°. They feed at first on succulent weeds near the cache, such as sow thistle (*Sonchus*), plantain, and even sorrel, but soon spread out, at first on foot, and feed on seedlings, particularly red clover cotyledons. At this time many may also be seen on dandelion heads and crocus blooms. The latter are sometimes damaged. Later they disperse by flight, at temperatures above 60°, and show a special preference for fields which have been recently (in January or February) seeded to clover. At this time they still show some signs of a gregarious instinct and, working in bands, they sometimes eat off all the seedling clover in large fields in a few days. After the beetles have been out of winter quarters for some time and weed seedlings have become abundant, the beetles scatter more and red clover is less damaged. Hence the damage to red clover seedings occurs suddenly and is soon over as the beetles move on to other food plants. It is therefore extremely difficult to combat damage to young clover fields since the damage is often complete, or nearly so, before it is noticed. Overwintered beetles are commonly swept from alfalfa, the vetches, and field peas in April.

Eggs probably are laid wherever the beetles are feeding. They have been found

rarely by us and in these cases they were in or near thick patches of clover or weed seedlings. On March 24, 1941, Arthur E. Bonn of Truck Crop Insect Investigations and the senior writer found eggs in abundance in cracks in the bare soil, a half-inch to an inch below the soil surface, near thick patches of volunteer clover seedlings in an old (third-year) red clover field near Gaston, Ore. On April 28, 1941, A. E. Bonn found eggs in a low, wet place in a field of common vetch and oats near Forest Grove. The eggs are usually laid in clusters of 4 or 5, and, in captivity, there are often intervals of a few days between ovipositions by individual females. The usual oviposition period is March to May, but doubtless some eggs are laid as long as any overwintered females survive, and a few of these may live all summer.

In 1941 A. E. Bonn kept five females in the laboratory from March 10 until they died in July, August, and September. The last survivor ceased oviposition on September 14, after laying 1404 eggs, and died on September 22. The average number of eggs laid by these 5 females was 1003, with a range from 745 to 1404. These females were fed alfalfa seedlings. We have observed some indication that the character of food of the female may have a considerable effect on oviposition. Females that were fed red clover seedlings in the laboratory lived long and laid many eggs; those fed mature leaves of clover, alfalfa, and vetch laid few eggs and were short lived.

The incubation period of the eggs varies with the temperature. During April 1929, in stender dishes in the laboratory, the egg period averaged 22 days. In 1930 eggs hatched in 8 to 11 days at a constant temperature of 75° F. Doane (1897) gave a description of the oval, yellow (Chamois, Ridgeway) egg, which is figured by Chittenden (1910), and stated that the eggs hatched in breeding jars in about 18 days. In the field in Oregon, in March, the egg period is 3 weeks or more.

The nearly mature larva is pale yellow, with a dark-brown head. The larvae probably develop on the roots of a variety of plants, legumes, grasses, and various weeds, but the host plants of the larvae may not be as varied as the food plants of the adults. Of the legumes, larvae have been reared through in the laboratory on the roots of alfalfa and to well grown larvae on red clover. Doane (1897) found larvae in abundance on the roots of sweet pea and alfalfa in California and sparingly on the roots of "other plants." H. O. Marsh (Chittenden, 1910) reported larvae on peanuts in California. As large numbers of beetles emerge in June and July in vetch fields and in fields of Austrian winter field peas, it seems likely that the roots of these legumes are also fed on by the larvae. It is known that larvae have matured on corn roots and they have been reared through on wheat seedlings in the laboratory. Larvae have also been found by the junior writer on the roots of canary grass and of *Polygonum*. Baker (1928) found larvae of *Diabrotica soror* on potato tubers in Washington State.

In the laboratory, on wheat seedlings, larvae completed their development in 23 days. The prepupal period, a nonfeeding stage, was 14 days, and the pupal period, in the soil, was 7 days. The adults remained in the soil 9 days before emerging. Hence the total period, in the laboratory, was 75 days from newly laid egg to the active adult. On wheat seedlings at a constant temperature of 75° F., the period of larval development to prepupae was 21 to 27 days, the prepupal period 14 to 22 days, and the pupal period 10 to 14 days. The only stage that was materially shortened at this higher-than-room temperature was the egg period. The total period from egg to adult at 75° was 50 to 75 days.

In a field under vetch and oats, where *Diabrotica 11-punctata* eggs were found on April 28, A. E. Bonn found third-stage larvae from 2 to 4 inches below the surface of the soil on May 22. Later, on June 6, pupal cells were found in the upper 2 inches of soil, and on June 16 adults were found.

Emergence of the new-generation beetles in the field has been noted as early as June 2 (in 1934 after an exceptionally early spring) and frequently by June 20. Newly issued beetles are most common in July.

The summer beetles have very diversified food habits, and the list of their recorded food plants would take up much space. However, Sell (1915) had difficulty in getting beetles in captivity to change from one food plant to another. They appear to be especially fond of flowers and pollen, and any succulent vegetation such as alfalfa, morning-glory, and the tender leaves of beans. Red clover blossoms are

eaten in July. The writers have repeatedly observed that the foliage of man-in-the-ground or wild cucumber, *Micrampelis oregona*, has been almost completely skeletonized by the beetles in 10 days to 2 weeks in July. Curiously enough, more than 90 per cent of the beetles that we have collected on this plant were males. Overwintered beetles are not attracted to this plant in spring (April and May). They also appear to be fond of sweets, as they have been observed on fruits of various kinds and eating aphid honeydew. A few have been taken in moth traps baited with fermented honey and molasses. In the fall, some have been observed to feed on slug bait—bran poisoned with 3 per cent of metaldehyde. In December 1940, 53 per cent of 38 beetles collected on this bait died in a few days.

Mating has been observed in August, September, and October. In summer field collections males have predominated until fall. Adults remain in the fields, especially alfalfa, until very late in the fall, and a few can be found all winter.

There are indications that the seasonal history may vary considerably with the locality. Thus eggs laid in May on land that was overflowed in March and April would produce later larvae and adults than eggs laid in March. Such oviposition on a large scale was observed on May 21, 1931, by T. R. Chamberlin on Wapato Lake, a temporary pond, near Gaston.

NUMBER OF GENERATIONS.—The general rule, at least in the Willamette Valley and to the north, appears to be that there is but one generation a year. Dissections of many beetles in summer and fall showed little or no egg development in the ovaries until winter (November to February), although most of the overwintering beetles were females that had been fertilized in the preceding summer and fall. In a few cases, however, eggs have been found in summer in field-collected specimens. Beetles collected near Medford on July 1, 1930, laid eggs in the collection vial. One female, taken near Forest Grove on August 2, 1929, had nearly full-grown eggs in the ovaries. Besse (1937) recorded females with fully developed eggs in September 1935 but stated that prior observations had indicated but one generation in a year. A fall generation was indicated near Coquille, Oreg., on the sea coast, when the senior writer collected full-grown larvae and pupae and noted the presence of newly issued adults in a cornfield on October 26, 1916. It is possible that the parent females in these instances were long-lived overwintered females and not new-generation beetles. This species is generally considered to have more than one generation a year in California.

It is possible that there may be an occasional and probably sparse second generation in certain areas of southwestern Oregon, perhaps only locally where conditions are right, but this is so rare an occurrence that it can be disregarded in the seasonal history, at least in the Willamette Valley and to the north. It is necessary that the soil be moist or wet for successful migration of first-stage larvae from near the surface to the roots. This factor would militate against a second generation in the Pacific Northwest because of the usually dry summers.

FACTORS IN NATURAL CONTROL.—Physical conditions which affect *Diabrotica 11-punctata* are deficient precipitation in spring, which is detrimental to the larvae because they are very dependent on moisture in the soil, and unusually cold winter weather. In December 1933 a minimum of 5° F., without snow cover, killed many beetles in a hibernation cache under observation. Such an occurrence, however, is rare in western Oregon.

Celatoria diabroticae (Shim.) is a common fly parasite of the adult beetles. As there is but one generation of beetles in a year and probably several generations of the parasites, the effects of this parasite are cumulative, and may be of considerable importance in natural control, even though the percentage of parasitized beetles may not be high at any one time. Arant (1929) has noted that most writers underestimate the economic importance of *C. diabroticae* as a natural enemy of *Diabrotica duodecimpunctata* (F.). He emphasized the percentage of parasitization of the overwintering beetles, the progeny of which, as larvae, cause serious injury to corn. Chittenden (1910) stated that *C. diabroticae* keeps the beetles of *D. soror* in check in certain seasons, appearing in great numbers in California.

In Oregon parasitization by this tachinid begins to be noticeable in newly emerged beetles collected in July. Most of the beetles collected at this time were

Table 1.—Parasitization of *Diabrotica 11-punctata* as shown by dissections.

Date	Number of Beetles			*Celatoria diabroticae* Larvae in Beetles			Merimithids in Beetles			Total Parasitization, Per Cent
	Male	Female	Total	Male	Female	Total	Male	Female	Total	
1930										
8/27– 9/2	85	5	90	6	2	8	0	0	0	8.9
9/27–29	60	20	80	2	4	6	0	0	0	7.5
10/20–23	13	30	43	2	4	6	0	0	0	14.0
10/30–11/3	13	67	80	1	8	9	0	0	0	11.3
1931										
2/13–19	2	30	32	1	9	10	0	2	2	37.5
7/18	38	7	45	1	0	1	0	0	0	2.2
9/24–10/1	108	62	170	20	15	35	0	0	0	20.6
1932										
3/8	0	67	67	0	19	19	0	13	13	47.8
1933										
4/5	0	44	44	0	12	12	0	8	8	45.4
1934										
7/21	47	27	74	2	2	4	0	0	0	5.4
8/25	62	7	69	21	0	21	0	0	0	30.4
1935										
4/6	0	100	100	0	31	31	0	60	60	78.0[1]
1938										
3/9	0	45	45	0	6	6	0	17	17	51.1

[1] Duplicate parasitization in 13 beetles.

males, but some parasitized females were taken. The percentage of parasitized beetles, as found by dissections, increases more or less steadily until April, when all are females. Examples of parasitization by this species and by mermithids are given in table 1.

A considerable percentage of the adults are often parasitized by mermithids, as yet unidentified, which sterilize the parasitized females and eventually kill them. It is likely that the extent of parasitization by these nematode worms varies from one locality to another, perhaps more than tachinid parasitization does. The two types of parasitization sometimes occur in one host. The total parasitization by both parasites combined sometimes exceeds 50 per cent in a large collection of female beetles of *Diabrotica 11-punctata* in March and April, as is shown in table 1. Thus a majority of the overwintered females may not be able to reproduce.

A staphylinid beetle was observed to have eaten several beetles in a hibernation cache under plantain on November 14.

Bryant (1912) recorded one stomach of a western meadowlark which contained 36 *Diabrotica soror* beetles. In April 1920 we found the remains of *D. 11-punctata* beetles in the stomach of a Brewers' blackbird, *Scolecophagus cyanocephalus*.

The fungus *Beauveria globulifera* (Speg.) often kills many beetles in their hibernation caches and also in the fields in fall and spring. More than 30 per cent of the female beetles collected in early spring sometimes die of this disease within 2 weeks. Hence this fungous disease is an important factor in natural control.

CONTROL.—Burning of fence rows after a flood on creek bottom land was tried with considerable success early in April 1931 by T. R. Chamberlin and E. A. Reuter of Forest Grove, Ore. The flood waters had caused countless millions of *Diabrotica 11-punctata* to accumulate in the drift along the fences. Distillate oil was used to burn over the wet stubble in the drift. In January 1936 the senior writer dusted a smaller concentration of beetles on fence posts after a similar flood, using a 1 per cent rotenone (ground derris) dust with good killing effect even though maximum temperatures ranged near 50° F. at the time. In the laboratory this dust paralyzed the beetles and none recovered, although some of them, kept at temperature of about 50°, continued twitching motions for 48 hours after treatment.

It is possible that effective measures could be taken against *Diabrotica* beetles that have congregated in hibernation caches. However, very few of these caches have ever been found. It would be necessary to warn farmers not to confuse aggregations of coccinellid beetles with those of *Diabrotica*, as many people do not differentiate between these beetles.

Dusting of the beetles in seedling clover fields might be effective, but the wetness of the early spring would be a handicap. Moreover, the beetles work on the red clover seedlings for such a short period that the grower would be unlikely to discover their presence in time to take the necessary control measures. There are also possibilities that a poisoned bait might be found attractive, but the same factors would militate against its effective use on red clover seedlings. Damage to clover seedings by the beetles could be avoided by seeding clover alone, or with rape, late in May or early in June, a common practice in some sections of the Willamette Valley where difficulty has been experienced in securing satisfactory stands of red clover seeded in grain fields.

Damage by the larvae to alfalfa seedings could be avoided by early spring plowing of the land to be seeded, followed by cultivation to keep it free of weeds until seeded, and by sowing the alfalfa early in June. This is recommended by agronomists as the best practice to insure an alfalfa stand in the Willamette Valley. It has been noticeable that all reports received of damage to alfalfa seedings by larvae of *Diabrotica 11-punctata* have been of fields seeded in May, usually on weedy ground which was worked up shortly before seeding. Damage to corn could also be avoided by late seeding, in the latter part of May, preferably following clean fallow for several weeks.

The larvae of *Diabrotica 11-punctata* become established in the fields in March and April and cease feeding late in May as a rule. Hence late seeding would bring up the crops after the larvae had ceased to feed. Every case of damage by larvae to alfalfa or corn that has come to our attention was caused by those which were already in the fields at the time of seeding. There might be a somewhat later seasonal history of the beetles on land that is overflowed late in the spring, but such lands would not be suitable for alfalfa.

SUMMARY.—Beetles of *Diabrotica 11-punctata* are destructive to seedling red clover soon after it comes up, and the larvae may damage young alfalfa and corn. Beetles have been found congregated in caches during the winter. Dispersal by flight begins at a temperature near 60° F. The females are long lived and may lay a thousand eggs or more. The eggs are laid beneath but near the surface of the soil and hatch in 8 to 22 days. The larval feeding period is about 3 weeks, and the total period of egg to active adult is 50 to 75 days. The roots of legumes, grasses, and weeds are eaten by the larvae. There is but one generation a year in the Willamette Valley, Ore. Most of the males die before winter. Deficient precipitation in early spring, extreme cold, a fungous disease, and parasites of the beetles are important factors in natural control. The beetles can be destroyed in hibernation caches, or in drift after floods, by the use of fire or by dusting them with 1 per cent rotenone dust. Late seeding of clover avoids damage by the beetles and late seeding of alfalfa and corn avoids damage by the larvae.—7-6-43.

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Commercial Pea Warehouse Tests of Fumigants Used Against the Pea Weevil in the Palouse Region[1]

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Pea warehousemen of the Palouse[2] have been fumigating peas for fifteen years or more and yet there has been no investigational work on pea weevil fumigation upon which to base their practices. Apparently the recommendations for fumigation of other stored products have been used.

With the tremendous expansion in pea acreage brought on by the war many new pea warehouses have been and are being built. Quarantine regulations require that all peas be fumigated or at least that they contain no live weevil and so still more warehousemen are confronted with fumigation guesswork. These investigations were undertaken to aid these new men in particular, and eventually to work out dosage-exposure-temperature schedules for all the fumigants and fumigating structures in use in the Palouse.

Most fumigation recommendations are based on temperatures of 70° F. and yet nearly all fumigation of peas in the Palouse is done at temperatures below 70° F. In fact, because of the crowded warehouse conditions, fumigation is carried on from harvest until seeding time the following spring or even the year around in some plants. As a result, fumigation is conducted at even sub-zero temperatures.

PROCEDURE.—Pea weevil fumigation was already being conducted on a large scale, commercial basis in the Palouse, so it seemed best to check directly on these practices rather than to conduct preliminary laboratory or small scale vault fumigations. Therefore, the data from these investigations are directly applicable to warehouse fumigation. Warehouses using liquid cyanide, disc cyanide, chlorpicrin, and methyl bromide were available for these tests.[3] No other fumigants are in general use against pea weevils in the Palouse.

Sample bags containing 12 to 36 ounces of peas (amount depending on the per cent of weevily peas) were placed, for the most part, inside pea sacks containing 100 to 140 lbs. of peas. The sacks containing the sample bags were then placed in the four corners of atmospheric fumigation vaults on the floor and on the top of the piles. The sacks were usually piled five high. Other sacks containing sample bags were placed in the center of the vault and just inside the door on the floor and on the top in both places. This gave a total of 12 samples for each experiment. (Occasionally it was necessary to place the sample bags between sacks of peas or on the floor rather than inside sacks in the respective positions.) The rest of the vault was filled with sacks as in regular fumigation practice. Two or three sample bags filled from the same lot of peas also were left in the warehouse outside the fumigation chamber as untreated checks for determination of mortality due to causes other than fumigation.

Dosage, exposure period, and temperature were recorded as well as the size of the room, room construction, and the load of sacks. After fumigation the sample bags were held for two weeks or more to allow ample time for the weevils to recover or die from the effects of the fumigant. The treated peas were stored at 35 to 50° F. to retard weevil activity so that they would not leave the peas. Only weevils taken from peas with closed windows (Fig. 1) were used on the theory that they would be hardest to kill, and a count from them only would be more uniform and more indicative of the effectiveness of the fumigant. Peas with closed windows were split with scalpels, taking care not to injure the enclosed weevils. The number of live and dead weevils were counted from these after the immature weevils had been discarded. Three lots of 100 adult weevils each was taken as the sample unit, although occasionally it was found that there were not enough mature weevils in a particular lot.

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[2] The Palouse is a hilly prairie section that covers most of the extent of Whitman county, Washington. Small portions occur in some adjoining counties. The western edge of the corresponding counties of Idaho are also Palouse prairie. The Palouse is the largest dry pea producing section in the country.

[3] The following made their warehouses available for these tests: Heglar & Mulkey, St. John; F. P. Feenan, St. John; Rogers Brothers Seed Company, Colfax; Mark Means Co., Lewiston, Idaho; F. H. Woodruff and Sons, Tekoa; Colfax Grain Growers, Steptoe. Their aid is gratefully acknowledged.

In the fumigation of bulk peas in bins the sample bags were dropped at the respective places as the bin was filled. Sample bags were placed in the four corners and center of the bin at both top and bottom for all positions. In addition, in some cases, sample bags were placed in all five positions when the bin was half full. The sample bags were collected when the bins were unloaded. Data on the load, dosage, temperature at the start of the fumigation, and were obtained with a mercury thermometer accurate within two degrees. Temperature records in the vault fumigations are usually average or mean temperatures obtained from the maximum and minimum temperatures recorded on a thermograph which was in the vault throughout the exposure period. Occasionally it was necessary to estimate mean temperatures from

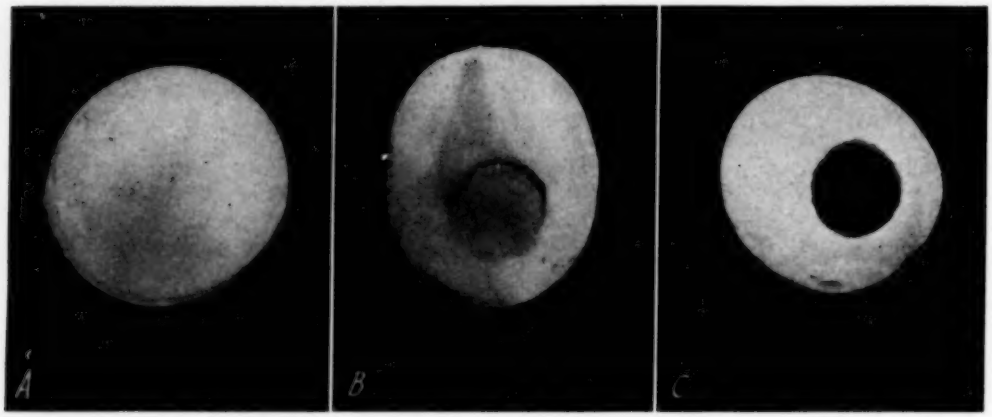

FIG. 1.—Peas showing (A) no window, (B) closed window with weevil inside, and (C) open window with weevil emerged. (Photos courtesy U. S. D. A. Pea Weevil Laboratory, Moscow, Idaho.)

temperature, exposure, and size and construction of the bin were recorded as in vault fumigation.

No tests were run this season on box car fumigation or entire warehouse fumigation although both practices are rather common in the Palouse.

The number of live weevils in the test bags prior to the start of each fumigation experiment was estimated on the basis of the per cent of live weevils in the untreated check samples, and from the total count of live and dead weevils at the completion of the test. The per cent survival after fumigation was then determined from this number and the number actually found alive in the samples.

In fumigation of peas for weevils, complete mortality is the only goal. Any test showing a survival of more than one and a fraction per cent was obviously a failure. Survival below that amount is infinitesimal because in the usual milling operations practically all weevil infested peas are removed.

Temperature records in the case of bin fumigation jobs are simply the temperamercury thermometer readings at closing and opening of the vault.

Twenty-five commercial warehouse fumigation experiments were successfully completed. Twenty-one atmospheric vault tests were run. The other four were bin fumigation jobs.

STRUCTURES.—All the vaults used were of similar construction. They were usually made of two layers of tongue and groove lumber with building paper between. Some used plyboard for the inner layer and shiplap for the outside, however. The vaults used in the chlorpicrin experiments were sheet metal lined, a factor which is taken into consideration in evaluation of the results since it was undoubtedly a more efficient structure. Doors were of variable construction but all seemed satisfactorily tight when closed as evidenced by only an occasional live weevil in front of the doors in the vault tests. Floors were made of tongue and groove flooring and in one case of concrete. All were apparently gas tight.

The bins used in the experiments were crib bins. They were lined with paper and

vertically laid tongue and groove flooring with the exception of the chlorpicrin test. In that bin, one wall was lined with paper and three-ply wood. The other walls were considered to be satisfactorily sealed by adjoining bins which were full of grain.

DISC CYANIDE TESTS.—With discoid cyanide eight vault tests were run (Table 1) with dosages of 1.14, 1.2 and 1.3 lbs. readily explains why weevils occasionally survived on the floor because cyanide gas, being slightly lighter than air, did not penetrate completely to the floor.

The vaults used in the discoid cyanide experiments were 7–8 ft. in height; but in loading, the 100 lb. pea sacks were stacked only 5 or 6 high. As a result, there was considerable air space above the peas.

Table 1.—Summary of 1942–43 vault fumigation tests.

FUMIGANT	LBS./1000 CU. FT.	MEAN TEMP. °F.	EXPOSURE HOURS	WEEVILS[1] ALIVE BEFORE FUMIGATION	WEEVILS ALIVE AFTER FUMIGATION	SURVIVAL PER CENT	REMARKS
Discoid Cyanide	1.14	35	14	2091	7	>1	6 on top. Sample bags, outside sacks.
	1.14	40	13	947	11	1+	Sample bags, outside sacks.
	1.14	41	12	2041	11	>1	All on floor. Sample bags, outside sacks.
	1.14	45	14	1234	15	1+	12 on floor.
	1.3	53	46	1556	0	0	
	1.3	57	15	1546	1	>1	On floor.
	1.2	59	15	1404	2	>1	On floor.
	1.2	62	16	1400	2	>1	On floor.
Liquid Cyanide	1.73	16	36	3463	138	10	88% on floor.
	1.79	30 at start	126	1288	0	0	
	1.73	40 estimated at start	80	1404	1	>1	
	1.8	43	91	1139	0	0	
Methyl Bromide	1.55	40	11	2000	407	20	95% on top near ceiling.
	1.60	43	40	1512	193	13	All on top near ceiling.
	1.85	58	17	1311	0	0	
Chloropicrin	3.00	12	31	1332	4	>1	Sheet metal lined vault for all tests of chloropicrin.
	2.62	28	63	1692	0	0	
	2.11	37	24	639	1	>1	
	2.18	39	24	1188	0	0	
	3.27	42	31	936	0	0	
	2.62	45 estimated	24	360	0	0	

[1] The number of weevils alive before fumigation was calculated, on the basis of the per cent alive in the untreated check samples, from the total number of adult weevils, both alive and dead, taken from the sample bags after fumigation.

per 1000 cu. ft. Mean temperatures ranged from 35° F. to 62° F. and exposure periods lasted 12 to 16 and 46 hours. In only the 46 hour test was every weevil found dead, but in only two tests did the per cent survival exceed one per cent and then only by a small fraction of a per cent. In nearly all cases the surviving weevils were found in sample bags located on the floor during the fumigation.

None of the fumigation vaults used for any of the experiments were equipped with false floors or circulating fans. This

LIQUID CYANIDE TESTS.—The four tests employing liquid cyanide (Table 1) were performed in two fumigating vaults at one warehouse. Dosage ranged from 1.73 to 1.8 lbs. per 1000 cu. ft. Mean temperatures ranged from 16° to 43° F. and exposure periods lasted 36 to 126 hours. Only at a mean temperature of 16° F. and an exposure of 36 hours did survival exceed the one plus per cent survival tolerance indicated in a previous paragraph as being within practical limits for satisfactory commercial fumigation. In only one

of the other tests did any weevils survive, and then only a single specimen. In the test that failed, 88 per cent of the surviving weevils were taken from sample bags that were on the floor during the fumigation. Here again cyanide gas did not penetrate to the floor.

At the warehouse using liquid cyanide, small electric heaters of the type used in electric street railway cars were located near the ceiling in one of the corners of each of the vaults. In close proximity to the heater a thermograph recorded a temperature of 30° F. when started, 65° F. in twelve hours, and over 90° F. after 48 hours. On another occasion maximum and minimum thermometers were placed near the floor on the wall farthest from the heater. At the start the temperature was 48° F. After the 91 hour exposure the maximum thermometer recorded 49° F. and the minimum recorded 37° F. So far as known the heater was functioning throughout the fumigation, and yet it failed to raise the temperature and actually permitted a drop in the part of the vault farthest away. There was no circulation other than convection and the vault was loaded to the ceiling, 7 ft. from the floor. In view of these data the influence of the heater has been disregarded in these tests. Even with a circulating fan and/or a false floor and some air space in the vault, it is questionable if the heater would have sufficient capacity to appreciably raise the temperature of a load of peas.

METHYL BROMIDE TESTS.—The three tests with methyl bromide were conducted in two vaults at another warehouse. A combination sack cleaner and exhaust fan was operated as a sack cleaner during a fourth fumigation test at this warehouse. As a result the gas was exhausted because of a damper that was not air tight and the experiment was ruined.

Methyl bromide was used at dosages of 1.55 to 1.85 lb. per 1000 cu. ft., at mean temperatures ranging from 40 to 58° F., and for exposure periods lasting 11 to 40 hours. Only the test using 1.85 lbs. per 1000 cu. ft. at a mean temperature of 58° F. for 17 hours resulted in complete mortality. At a mean temperature of 43° F. and a dosage of 1.60 lb. for an exposure of 40 hours the survival was 13 per cent. In the 11-hour exposure at 40° F. survival was 20 per cent.

Circulation was not provided in the methyl bromide fumigations nor in any of the others. In addition the vaults were loaded to the ceilings, 10 ft. high. All of the surviving weevils in the 40 hour exposure were found in top samples, and 95 per cent of those in the 11-hour exposure were also from the top of the vault. Methyl bromide gas being heavier than air had penetrated to the floor and, due to lack of circulation and the fully loaded condition of the vault, was not dispersed in the upper levels.

CHLOROPICRIN TESTS.—Six tests with chloropicrin were run in two sheet metal lined vaults at still another warehouse (Table 1). Dosage ranged from 2.11 to 3.27 lbs. per 1000 cu. ft. Mean temperatures ran from 12° F. to 45° F. and exposure periods lasted 24-63 hours. All tests were highly satisfactory. In fact, four living weevils in one test and one living weevil in another, both well below the 1-per cent level, were the only survivals.

Two factors must be taken into consideration when comparing the results from this fumigant with the others. First, the sheet metal lined vaults provided a structure superior to any of the others. Second, none of the tests were in dosage, exposure, or temperature ranges wherein imperfect control resulted as in some of the tests with the other fumigants, all of which were used at considerably lower dosages.

On the other hand, some of the other fumigants did not perform satisfactorily at mean temperatures well above the lowest mean (12° F.) for chlorpicrin.

No effort was made to obtain rapid volatilization or even distribution of the chloropicrin. The liquid was simply thrown over the sacks in the vault and the door closed.

Considerable difficulty was experienced in aerating the peas after fumigation with chloropicrin especially at the lower temperatures. The gas could be detected in the peas several days after the colder tests, and caused irritation of the eyes and even nausea among workmen.

Apparently no ill effects on germination resulted from the high dosage. This was probably because the peas were well cured for the 1942 harvest and had a minimum moisture content. Trouble might be experienced if the per cent moisture in the peas was high due to rain at harvest time.

BIN FUMIGATION TESTS.—One test with discoid cyanide, two tests with methyl bromide, and one test with chlorpicrin constituted the extent of tests on bin fumigation (Table 2). Only chloropicrin proved satisfactory. Bulk handling of peas is becoming a rather common practice in the Palouse, possibly hastened by the shortage of burlap bags due to the war. Therefore, it is regrettable that these tests were so few and the results for the most part negative. Perhaps the tests do offer some worth while information, however.

Table 2.—Summary of 1942–43 bin fumigation tests.

FUMIGANT	LBS./1000 CU. FT.	TEMP. AT START °F.	EXPOSURE HOURS	WEEVILS[1] ALIVE BEFORE FUMIGATION	WEEVILS ALIVE AFTER FUMIGATION	SURVIVAL PER CENT	REMARKS
Methyl Bromide	2.61	46	24	1322	414	31	Live weevils in top of half-filled bin.
	2.61	50	24	2684	141	5	Live weevils in top of half-filled bin.
Discoid Cyanide	1.31	49	15	752	380	50	Discs lowered in burlap sack 1 lb. when half full; 2½ lbs. when full. Live weevils, bottom and half way. Bin half full.
Chloropicrin	3.50	64	Normal dissipation of gas, actually 1056 hrs.	1144	9	>1	Seven live weevils in spout, two on top.

[1] The number of weevils alive before fumigation was calculated, on the basis of the per cent alive in the untreated check samples, from the total number, both alive and dead, taken from the sample bags after fumigation.

Discoid cyanide was used in the same bin when it became evident that methyl bromide was unsatisfactory. The cans were opened and the discs placed in a burlap bag which was lowered into the bin when the peas were half loaded and again when all loaded. The surviving weevils in this case were found at the bottom and middle of the bin. As used, cyanide proved inferior to methyl bromide.

Again, as in the vault fumigations, in the two methyl bromide tests, the liquid was allowed to flow through a pipe into the top of the bin when one-fourth loaded, again when half full, a third time when three-fourths loaded, and finally when all the peas were in. About 80,000 lbs. of peas were loaded in the bin for a fumigation. This quantity made the bin (10 by 10 by 46 feet) only a little more than half full. The bin had flooring over the top with a tight fitting trap door. All surviving weevils were found in sample bags from the top of the bins, indicating that methyl bromide penetrated through the mass of peas and settled in the lower part of the bin in spite of periodic applications as the bin was filled. The two tests were run in the same bin on different dates. All conditions were identical except for temperatures of 46° and 50° F. Apparently this difference in temperature made a difference of 5 to 31 per cent in survival of weevils.

chloropicrin was used at a considerably higher dosage than the other fumigants. In addition, it was used at the highest temperature (64° F.) of any of the tests, and was allowed to remain longer than any of the others, 44 days, since the bin was used as storage for the peas for that length of time. As a result, the gas was allowed to stay in the peas until exhausted by normal diffusion. However, the bin was open at the top and the peas were simply covered with loose fitting pieces of canvas and tarpaulin after the chloropicrin was applied. One-half the dosage was sprinkled on the peas when half loaded and the rest when full. The bin, 12 by 10 by 15 ft., was loaded to within a foot of the top. Seven of the nine surviving weevils were found in the spout. Judging from the amount of gas that escaped below the bin, the spout closure was far from gas tight.

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chloropicrin was used at a considerably higher dosage than the other fumigants. In addition, it was used at the highest temperature (64° F.) of any of the tests, and was allowed to remain longer than any of the others, 44 days, since the bin was used as storage for the peas for that length of time. As a result, the gas was allowed to stay in the peas until exhausted by normal diffusion. However, the bin was open at the top and the peas were simply covered with loose fitting pieces of canvas and tarpaulin after the chloropicrin was applied. One-half the dosage was sprinkled on the peas when half loaded and the rest when full. The bin, 12 by 10 by 15 ft., was loaded to within a foot of the top. Seven of the nine surviving weevils were found in the spout. Judging from the amount of gas that escaped below the bin, the spout closure was far from gas tight.

DISCUSSION OF RESULTS.—On the basis of these tests, cyanide discs appear to give satisfactory results in vault fumigation at a dosage of about 1.25 lbs. per 1000 cu. ft. for an exposure of 12 to 15 hours at mean temperatures as low as 35° F. Slatted false floors or a circulating fan should improve these conditions and make destruction of weevils on the floor more certain. Even so, overnight exposure, dosage of 1.25 lbs. per 1000 cu. ft. or less, mean temperature as low as 35° F., and survival of usually less than 1 per cent, in peas already practically free of weevil as a result of gravity mill cleaning, indicate a fumigation procedure already commercially satisfactory. The increased benefit to be obtained by false floors appears slight to the average warehouseman since he believes, without trying them, that false floors interfere with trucking. A circulating fan, however, is not even considered to be troublesome and could easily be installed and operated.

In crib bin fumigation, cyanide discs would perform much better if placed at the bottom of the bin, and at frequent intervals as the bin is loaded, rather than as used in the test. Even so, the product might not prove satisfactory. It was not designed for such use. Other cyanide materials (liquid cyanide or preferably granulated calcium cyanide) should prove much more efficient for bin fumigation.

The tests indicate that liquid cyanide at 0.75 lbs. per 1000 cu. ft. is a satisfactory vault fumigant at mean temperatures of 30–40° F. for exposures of 80 to 126 hours. Undoubtedly the minimum conditions were not reached because liquid cyanide should give results comparable to disc cyanide. Evidently the dosage could be reduced somewhat at these or higher temperatures and a greater quantity might have given satisfactory results in the 16° F. test. The influence of the electric heaters used in these vaults has been disregarded since their ability to raise the temperature of the peas appears insigficant. A circulating fan, a false floor, and some air space at the top of the vault should collectively or singly improve the efficiency of liquid cyanide fumigation.

Methyl bromide at 1.75 lbs. per 1000 cu. ft. for an exposure of 17 hours and a mean temperature of 58° F. appears to be a satisfactory pea weevil fumigant for use in vaults. Apparently at mean temperatures below 50° F. it is unsatisfactory although the tests are too few to be conclusive. Lack of circulation may have been the principle reason for failure at the lower temperatures. The inclusion of a circulating fan plus some air space at the top of the room should improve the results from this material. Difficulty was experienced in ejecting the gas from the cylinder at the lower temperatures.

As a crib bin fumigant methyl bromide appears unsatisfactory. It penetrates to the bottom of the bin where perfect control is obtained, but in the upper part weevils survive. In a bin it is impossible to install means of circulating the gas so that this difficulty cannot be overcome.

Delayed mortality was very evident after fumigation with methyl bromide. Upon being warmed several days after treatment the weevils would move but could not coordinate their actions.

Chloropicrin, on the basis of these tests, appears to be the most versatile fumigant in use against the pea weevil in the Palouse region. In the tests reported it is readily apparent that the minimum conditions were not met. Every fumigation test was a commercial success. About 2 lbs. per 1000 cu. ft. for 24 hours at a mean temperature of about 40° F. gave satisfactory vault fumigation results. Three lbs. per 1000 cu. ft. for 30 hours at a mean temperature of 12° F. also gave satisfactory results. Roughly, this agrees with one manufacturer's "rule of thumb" schedule which calls for an increase or a decrease of 0.25 lb. per 1000 cu. ft. for each decrease or increase in temperature of 10° F. or fraction thereof. It is recognized that the sheet metal lined vaults probably increased the efficiency of chloropicrin in comparison with the other fumigants. Neither atomization of the liquid nor circulation in the vault appears necessary for satisfactory results.

The single test with chloropicrin as a crib bin fumigant included an extremely high dosage (3.5 lbs. per 1000 cu. ft.), high starting temperature (64° F.), and a prolonged exposure period (1056 hours). The results obtained were commercially satisfactory but it is difficult to make any generalizations from the data. Apparently chloropicrin will prove to be a satisfactory bin fumigant for use against the pea weevil under the fumigating conditions of the Palouse region.

SUMMARY AND CONCLUSIONS.—This is an investigation of pea weevil fumigation as commercially practiced in the dry pea producing section known as the Palouse region. In this region, fumigation is conducted at temperatures far below those generally recommended in fumigating practice.

1. Discoid cyanide proved effective in vault fumigations at 1.25 lbs. per 1000 cu. ft. for exposures of 12 to 15 hours at mean temperatures as low as 35° F. As used in bin fumigation it did not prove satisfactory.

2. Liquid cyanide proved satisfactory at 1.75 lbs. per 1000 cu. ft. with mean temperatures of 30 to 40° F. for exposures of 30 to 126 hours. Undoubtedly these data do not represent the minimum conditions as they should be comparable with discoid cyanide. At 1.75 lbs. per 1000 cu. ft. for 36 hours at a mean temperature of 16° F. it was not satisfactory.

3. Methyl bromide at 1.75 lbs. per 1000 cu. ft. for an exposure of 17 hours at a mean temperature of 58° F. was a satisfactory vault fumigant. At mean temperatures below 50° F. methyl bromide appeared unsatisfactory. As a bin fumigant it was also unsatisfactory.

4. Chloropicrin was effective as a vault fumigant at a mean temperature of 12° F. with a dosage of 3 lbs. per 1000 cu. ft. and an exposure of 30 hours. Apparently the dosage can be decreased about 0.25 lb. per 1000 cu. ft. for each 10° F. rise in temperature. As a bin fumigant under nearly optimum conditions it also proved satisfactory.

5. The use of circulating fans with cyanide or methyl bromide ought to improve results. Fans do not seem to be needed with chloropicrin. False floors also should improve results with cyanide.

These tests are too few to give more than trends and indications. Nevertheless they do provide some information on low temperature fumigation not previously available and they provide a working basis for subsequent fumigation, whether commercial or experimental.—8-31-43.

Asparagus Miner Really Not a Pest[1]

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The asparagus miner, *Agromyza simplex* Loew, has become very abundant throughout the greatly expanded asparagus acreage of Eastern Washington during the past five years. Great numbers of miner flies have become especially noticeable during the cutting season, and mines have been found on nearly every stalk at the end of the season. In addition, asparagus plants over entire fields were found to be turning yellow prematurely in the fall and the presence of mines on the stalks indicated that the asparagus miner might be responsible.

The asparagus miner appeared to be a pest approaching outbreak proportions. Accordingly the life history and habits of the asparagus miner were studied preliminary to developing means of control. Injury to the host plant caused by mining was studied at the same time. These studies were conducted at the Irrigation Branch Experiment Station near Prosser during three summer seasons, 1940–42, and in addition field observations were made in the vicinity of Sunnyside, Prosser, Kennewick, Walla Walla, and Dayton, Washington. These studies never reached the "control" stage and revealed that the impending outbreak was non-existent.

REVIEW OF PREVIOUS WORK.—Barnes (1937) has very ably presented a discussion of published information on the asparagus miner and has included a list of the references. He has given a detailed account of the morphology and has included a discussion of parasites. The habits, life cycle, and seasonal abundance as observed at Harpenden, Hertfordshire, England, are also recorded. A reprint of this excellent article served as handbook during our observations.[2] Barnes, however, failed to give a very adequate idea as to the damage done or the importance of the insect

[1] Published as Scientific Paper No. 558, College of Agriculture and Agricultural Experiment Station, State College of Washington.

[2] F. A. Kirsch and Norton Wilson located at the Irrigation Branch Experiment Station as summer assistants, collected most of the detailed information for this study.

as a pest. According to his observations very little damage was done in mature asparagus beds, except that stems attacked by the asparagus miner appeared to be more attractive to attack by *Lonchaea flavidipennis* Zett., which seriously damages asparagus stems in England. By reviewing control investigations of other writers and mentioning that he tested some of their suggestions, Barnes at least implied that the miner was of sufficient importance to require control.

In Germany, M. Dingler[2] has published four papers which are, at least in part, concerned with the asparagus miner. He concludes that the asparagus miner is too rare to be considered as anything more than a potential pest. He does, however, propose a number of control measures in conjunction with the control of the asparagus fly *Platyparea poeciloptera* Schrank, the larvae of which bore into the stems of asparagus in continental Europe. The asparagus miner has also been recorded in other accounts from Germany, Hungary, France, and England.[1]

Agromyza simplex was described from the eastern United States in 1869 but at that time was not known to feed on asparagus. Sirrine (1900) was the first to rear the flies from puparia in asparagus stalks. It was he who proposed the present common name. He reported that the asparagus miner "simply works beneath the outer bark or epidermis and devours all the green portion of the plant between the epidermis and the bast, or wood, fiber. Five or six of the maggots will usually completely girdle a stalk . . . no noticeable injury from its work has ever been detected on cutting beds . . . . Possibly the fact that the structure of the asparagus plant is such that it can withstand girdling much better than more woody plants accounts for the injury not being noticed." Sirrine was on the right track but did not follow it up and reported instead, "considerable injury from their work was observed on seedling and newly set beds. The injury showed itself by the plants turning yellow and finally dying much earlier than they naturally do . . . . Although the injury to cutting beds is not noticed, there is no doubt that the plants are materially weakened, later, by the attacks of this pest." Sirrine proposes control measures under the heading "Remedies."

[1]For references see Barnes (1937).

Chittenden (1907) states that, "Until the year 1906 it (the asparagus miner) had not been recognized as doing injury to cutting beds . . . " and that "mines . . . are frequently so abundant that they have the effect of girdling . . . ." He records the distribution as Massachusetts to Tennessee and states that it has appeared in California as reported in California Agricultural Experiment Station Bulletins 165 and 172. He too proposes "Remedial Measures" as his notes indicate an insect which "bids fair to become a pest of considerable importance."

Fink (1913) has given the most comprehensive American account on the asparagus miner but his study was undertaken "with the view of obtaining a more accurate knowledge of its habits and life history and at the same time of determining how it can best be controlled." He takes for granted that the asparagus miner is capable of causing considerable damage especially to seedlings and newly set asparagus beds, and further states that the injury, yellowing, and wilting of asparagus stalks is frequently attributed to other causes such as wireworms, centipedes, and drought, especially by growers. He concludes with a discussion of "Methods of Control" for the miner "as a pest to be contended with."

Drake & Harris (1932) have included a short account on the asparagus miner in their popular discussion of asparagus insects. They consider that injury by the asparagus miner is quite severe, yet unnoticed by growers or attributed to other causes. Premature wilting and yellowing of the stalk and foliage often resembling severe drought is credited to girdling of the stalk by the mining of the maggots. Their control recommendations apparently are based on the publications previously reviewed.

Essig (1936) refers to the asparagus miner as follows: "although the mines practically cover the entire surface of the stalks, little damage in commercial plantings appears to result from their attacks. The stalks are, however, occasionally killed. . . . Cutting and burning the stalks and winter flooding of the fields effectively control the insect."

LIFE CYCLE, SEASONAL HISTORY, AND HABITS.—Asparagus miners pass the winter as puparia in the mines in asparagus stalks, or stubs if the stalks are cut

and removed from the field in the fall. Volunteer asparagus in orchards and along roadsides provides great numbers of stalks for the overwintering puparia. The dark brown puparia are readily discerned under raised areas of the thin asparagus stalk epidermis. Often the epidermis over the mines is broken and reveals the puparia.

First generation flies emerge in April and May. The first flies may be expected shortly after the first asparagus shoots appear. The small, metallic black flies about 3 mm. long are often seen in great numbers flitting about seedling asparagus in the cutting beds. According to other workers there is a pre-mating period of 2 to 13 days and oviposition occurs a day or two after mating. Difficulty was experienced in keeping the flies alive in the insectary so that no data were collected on these functions or the longevity of the flies. The maximum life of flies in the insectary was 4 to 10 days. But as indicated, flies of the first generation were present in the field over a two-month period.

Eggs are deposited just beneath the epidermis of the asparagus stalk at about the ground level. The female fly may even crawl down through crevices in the soil about the stalk in order to oviposit in the stalk below the ground level. Fink, quoted by Barnes, gives an excellent account of the mechanics of oviposition. The flies apparently prefer to deposit eggs in stalks which have grown past the cutting or marketable stage.

The length of the egg stage alone was not determined. The time from oviposition to pupation including three larval instars lasted 15–18 days in insectary rearings during June and July. Upon hatching the larvae proceed to mine in the soft, green parenchymous tissue, the cortex, just under the epidermis. Apparently they are unable to penetrate the lignified pericyclic fibers which lie just inside the cortex. As a result the miners do not invade the conductive or meristematic tissues of the asparagus plant which lie inside the woody pericycle. Remember, asparagus is a monocotyledonous plant. The mines ramify, there is no pattern, rhyme or reason to the direction they may go. At first the mines cannot be discerned but as the miners progress, the epidermis over the mines dies and becomes brown or transparent, often flaking off. If the mines are at all numerous, the stalk soon presents the "girdled" appearance so often mentioned. Actually, however, the asparagus stalk has not been "girdled" in the sense that the conductive tissue or cambium has been destroyed as in dicotyledonous plants.

Pupation occurs at the end of the mine whether this be a foot above the ground or below ground level. The pupal period lasted 22 to 25 days in insectary rearings during July.

During the summer about a month and a half is required for the completion of a life cycle. From this it was apparent that three generations could complete development during the asparagus season, April to October, in the Yakima Valley of Washington. Field observations (collection of adult flies by sweeping asparagus at frequent intervals with an insect net and comparison of the number of flies collected) readily confirmed the fact that three generations of asparagus miners occurred during the years 1940 and 1941. The first generation flies appeared in April and May and were present in the field until about June 20. Second generation flies were present from late June to early August. Third generation flies were in the field from the middle of August through September.

ECONOMIC IMPORTANCE.—The great abundance of flies in the field and the presence of numerous mines on nearly all asparagus stalks in the fall readily gives the impression that the asparagus miner is an insect pest of serious economic importance. Especially when entire asparagus fields turn yellow prematurely in late summer the insect is classed as a serious pest.

Observations on the feeding habits of the maggots have shown that only the cortex in the basal part of the stalk is destroyed. The food and water transportation system of the asparagus plant is not touched. The cortex has no vital function in the life process of the asparagus stalk. The cortex is parenchymous tissue which contains chlorophyl. Its sole function is the manufacture of food and the proportion of food produced in the lower part of the stalk is slight indeed compared with that manufactured by the rest of the plant. Heavily mined asparagus stalks may remain green until frost; whereas, a nearby unmined stalk may turn yellow prematurely. The premature yellowing of

asparagus in late summer, and the wilting and dying asparagus stalks credited by other writers to the attack of the asparagus miner, has been credited in Eastern Washington to infection by *Fusarium oxysporum* Schlecht by Cohen & Heald (1941). The fungus attacks both immature and mature plants and is widespread throughout the country.

Cohen suggested at another time (unpublished) that the mines of the asparagus miner might serve as an entry for the fungus. However, this possibility seems rather remote. The female fly inserts the egg beneath the epidermis on an exposed portion of the stalk, and although the puncture may be below the ground level it is not in direct contact with the soil. The maggot in mining does not break the epidermis. It is a closed mine. The dead epidermis may slough off but by that time the tissue cut by the miner has had time to become calloused. Six weeks after the egg is laid the fly emerges from the puparium in the mine and breaks the epidermis to escape to the outside. The fly emerges three weeks or more after the cessation of feeding by the maggot so again the tissue has had ample time to become calloused before the epidermis is broken. It seems that normal harvesting and cultivation practices which cut the stalks and crowns, afford the avenue of entry for the *Fusarium* rather than the asparagus miner.

At no time in our observations was it possible to associate asparagus miner injury with dead or dying asparagus stalks. Nor was it possible to associate asparagus miner injury with reduced yields of asparagus. However, since the plant is providing food for the insect, some reduction in yield or length of life of the plant must occur, although it is probably very slight. The loss could only be determined by crop yield and miner infestation records throughout the 15-year life of several asparagus plantings. The loss, to all gross appearances, is so slight that such a study would be a waste of time and money as asparagus production is already the most lucrative crop for truck growers in eastern Washington even in spite of *Fusarium* infection. Further, there are many important truck crop insect pest problems which do require attention.

SUMMARY AND CONCLUSIONS.—In spite of its abundance as an insect feeding on asparagus, the asparagus miner appears to be of no economic importance in eastern Washington.

In other regions the asparagus miner has been accused of causing yellowing, wilting, and dying conditions in asparagus. This damage has recently been credited to infection by *Fusarium oxysporum* Schlecht in eastern Washington. In addition the miner has been suspected of opening an avenue of entry for the *Fusarium*, but its importance in this respect is slight compared with plant injuries caused by cultivation and harvesting.

The asparagus miner produces no serious effect on the asparagus plant exacting only a slight toll in the food it consumes while mining the cortex tissue. Since the injury is so slight and apparently has no effect on the economics of asparagus production, the cost of determining the exact amount of injury is not warranted in view of more pressing wartime insect control problems.

The asparagus miner will no longer be considered as an asparagus insect pest in Washington. It requires no control. Other investigators would do well to take cognizance of this fact and actually determine the economic importance of the insect before recommending or suggesting control measures which date back as much as 40 year.—7-1-43.

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Aphid Increase and Plant Injury Following the Use of Calcium Arsenate on Peppers

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An increase in the numbers of aphids following the use of certain materials on plants to control insect pests other than aphids has been commonly noted for many years. Folsom (1927) reported a marked increase in the populations of the cotton aphid, *Aphis gossypii* Glov., following the use of calcium arsenate for boll weevil control. It has also been shown (Moore 1935) that the potato aphid, *Macrosiphum solanifolii* (Ashm.), increases in abundance on potatoes that have been sprayed with bordeaux mixture. When calcium arsenate was first used on peppers in 1928 as a control for the pepper weevil, *Anthonomus eugenii* Cano, the green peach aphid, *Myzus persicae* (Sulz.), became so numerous that it caused serious damage to the crop. Heavy aphid infestations on peppers that year were observed adjacent to roads where much road dust had drifted in. As a result of these experiences pepper growers were cautioned (Elmore *et al.* 1934) that aphid infestations could be expected following the continued use of calcium arsenate, especially when treatments were begun early. Although calcium arsenate has been used successfully to combat the pepper weevil on peppers in some seasons without causing serious aphid infestations, its use during the last four seasons (1939 to 1942) has usually resulted in marked increase in aphid abundance and subsequent plant injury.

Rainwater & Bondy (1941) experimented on the control of the cotton aphid by adding aphicides to the insecticides used for boll weevil control. Derris and nicotine were each added to calcium arsenate, and derris was also added to cryolite and to barium fluosilicate. The aphicides in each case reduced the aphid population. The derris-calcium arsenate combination, especially, caused a marked decrease in aphid abundance as compared with calcium arsenate alone.

This led the authors, in the control experiments on the pepper weevil in 1941, to try the derris-calcium arsenate combination as well as a derris-cryolite combination to prevent the development of the aphids.[1] In the area where the plots were located, San Juan Capistrano, Calif., the aphid population was low throughout the year, the highest being five aphids per leaf in the calcium arsenate plots, and here no damage was caused. The aphid population was materially less, however, in plots where the derris was added to the calcium arsenate or cryolite. In other areas, in commercial fields treated with the derris-cryolite combination, there was no material increase in aphid abundance, but in the fields where calcium arsenate was used, with or without derris, there was a considerable increase in aphid abundance, which caused severe plant injury and defoliation.

In 1942, further experiments were conducted to compare the effectiveness of various aphicides when combined with calcium arsenate or cryolite.

MATERIALS AND METHODS.—Cryolite diluted with talc so that the final dust mixtures contained 50 and 70 per cent of sodium fluoaluminate,[2] respectively, were used alone and in combination with rotenone-bearing powder, with pyrethrum, and with free nicotine. Calcium arsenate undiluted was used in the same combinations. The rotenone combinations were obtained by mixing enough of a derris powder with the cryolite or calcium arsenate to impart 0.5 per cent of rotenone to the final mixture. The pyrethrum combinations were obtained by impregnating the dust materials with enough pyrethrum extract to impart 0.1 per cent of total pyrethrins to the final mixture. The nicotine combinations were obtained in a similar manner so that the final mixture contained 1 per cent of nicotine.

Peppers grown in coastal regions of California are subject to frequent fogs and heavy drew. Three pepper fields in one area were used in these experiments, one

[1] The use of rotenone-containing insecticides is restricted by War Production Board Conservation Order No. M-133, insofar as insects affecting vegetables are concerned, to the following purposes: On peas, for protection against the pea weevil and the pea aphid; on beans, for protection against the Mexican bean beetle; and on cole crops other than cabbage, including broccoli, brussels sprouts, cauliflower, kohlrabi, mustard, kale, turnips, and collards, for protection against caterpillars and aphids.

[2] Percentages of cryolite given here and hereafter in this paper refer to percentages of sodium fluoaluminate.

of a common pungent variety known as California chili, one of Spanish paprika, and one of Hungarian paprika. Each field was divided into 72 plots of 0.02 acre each, arranged in 6 randomized blocks, each 3 plots wide by 4 long. The experimental design was the same in all the fields, except that in one field mill-run cryolite, 50 per cent and 70 per cent, respectively, was substituted for 2 of the calcium arsenate treatments.

All materials were in dust form and were applied with rotary hand dusters. and the same plants were picked to obtain yield data.

Aphid abundance was determined by counting the numbers of aphids per leaf on one selected leaf from every fifth plant in the five central rows of each plot, making a sample of 25 leaves per plot. The number of aphids per leaf was used as the index of aphid abundance.

The data were analyzed by the method of analysis of variance as an aid to proper interpretation.

RESULTS.—Table 1 shows a summary of

Table 1.—Degree of pepper weevil infestation, number of aphids, degree of plant injury, and yield of paprika in one field, following applications of various insecticide combinations for pepper weevil control, Remmers Ranch, San Juan Capistrano, Calif., 1942.

INSECTICIDE	PODS INFESTED BY WEEVILS	AVERAGE APHIDS PER LEAF	PLOTS SHOWING VARIOUS DEGREES OF PLANT INJURY 1	2	3	4	PODS PER PLANT	YIELD PER ACRE GREEN WEIGHT
	Per Cent	*Number*	*Number*				*Number*	*Tons*
Cryolite 50%	1.0	9.0	6				21.5	10.5
Cryolite 50%, rotenone 0.5%	2.5	7.3	6				19.2	9.2
Cryolite 50%, pyrethrins, 0.1%	4.5	7.7	6				22.8	10.2
Cryolite 50%, free nicotine 1.0%	2.2	6.8	6				21.3	10.0
Average	2.5	7.7					21.2	10.0
Cryolite 70%	0.3	11.8	6				21.7	10.4
Cryolite 70%, rotenone 0.5%	1.2	7.5	6				22.7	10.6
Cryolite 70%, pyrethrins 0.1%	0.8	10.2	6				21.2	8.6
Cryolite 70%, free nicotine 1.0%	2.0	8.0	6				22.8	10.5
Average	1.1	9.4					22.1	10.0
Calcium arsenate	0.8	24.5				6	19.3	6.5
Calcium arsenate, rotenone 0.5%	1.0	13.8			6		20.5	7.6
Calcium arsenate, pyrethrins 0.1%	0.7	19.3			6		24.1	9.9
Calcium arsenate, free nicotine 1%	0.7	17.7		1	5		22.4	8.2
Average	0.8	18.8					21.6	8.1
Amount required for significant difference at odds of 19 to 1	2.7 1.4	3.5 2.2					3.4 2.1	2.3 1.2

[1] 1. No injury.
2. Heavy sooty mold fungus.
3. Plant injury, some defoliation and pod shriveling.
4. Severe plant injury, much defoliation and pod shriveling.

The regular treatment schedule called for seven applications at 7-day intervals, but it was thought best to make an eighth application 10 days later in one field, and 16 days later in another, to protect unusually late pods. The first application was made when the first pods began to set and the last when all but a few of the late pods were mature. Approximately 15 pounds of the dust mixtures per acre were used at the first application, with a gradual increase to 20 pounds per acre at the last application.

The degree of pepper weevil infestation was determined by examining all the pods on five plants selected systematically in each plot. The seventh and fifteenth plants in the third and fifth rows and the eleventh plant in the fourth row were examined for weevil infestation records,

conditions in the Spanish paprika field at harvest. The aphid population was greater in this field than in either of the other two. The aphid population was significantly higher in the plots treated with only calcium arsenate than in those treated with only cryolite. Plant injury in all calcium arsenate-treated plots was severe. This injury was at first thought to be due entirely to aphid abundance, but further observation revealed that the degree of injury was not entirely consistent with the number of aphids per leaf. For example, some of the calcium arsenate plots were no more heavily infested than some of the cryolite plots, yet all the calcium arsenate-treated plants were damaged, while none of the cryolite-treated plants were injured. Plant injury was also reflected in yield per acre. Although there is a sig-

nificant difference between the results with cryolite and those with calcium arsenate in the number of aphids per leaf, the significant difference in yield between the cryolite and calcium arsenate plots cannot be attributed to aphid damage alone. For example (Table 1), there is no significant difference in aphid population between 70 per cent cryolite used alone and calcium arsenate-derris dust, but in crop yield there is a significant difference in favor of cryolite alone over calcium arsenate-derris. Differences in weight were due to premature pod shriveling because of plant injury.

Table 2.—Degree of pepper weevil infestation, and number of aphids following application of various insecticide combinations for pepper weevil control. Summary of three fields, Remmers Ranch, San Juan Capistrano, Calif., 1942.

Insecticide	Pods Infested by Weevils	Average Aphids per Leaf	
	Per Cent	*Number*	
Cryolite 50%		7.0	
Cryolite 50%, rotenone 0.5%		5.3	
Cryolite 50%, pyrethrins 0.1%		6.0	
Cryolite 50%, free nicotine 1.0%		5.4	
Average	2.0		5.9
Cryolite 70%		7.6	
Cryolite 70%, rotenone 0.5%		6.1	
Cryolite 70%, pyrethrins 0.1%		7.3	
Cryolite 70%, free nicotine 1.0%		6.0	
Average	1.1		6.8
Calcium arsenate		21.2	
Calcium arsenate, rotenone 0.5%		12.7	
Calcium arsenate, pyrethrins 0.1%		16.0	
Calcium arsenate, free nicotine 1.0%		14.8	
Average	0.7		16.2
Amount required for significant difference at odds of 19 to 1	0.8	2.2	1.3

Since there were no untreated plots in the field to cause reinfestation of treated plots, the degree of pepper weevil infestation was low. On the basis of percentage of pods infested by the pepper weevil there were no appreciable differences in the degree of effectiveness of 70-per cent cryolite and calcium arsenate, but each of these materials was more effective than 50-per cent cryolite.

The results of treatment in all three fields are summarized in table 2. The yield per acre is omitted from this table because much of the crop in one field was picked for the green market. In all three fields aphids were significantly more abundant in calcium arsenate-treated plots than in cryolite-treated plots, regardless of any aphicides used. The cryolite-aphicide combinations caused no significant decrease in aphid abundance compared with cryolite alone. Derris-calcium arsenate was slightly more effective than nicotine-calcium arsenate or pyrethrum-calcium arsenate in aphid control, and all these reduced the aphid population as compared with calcium arsenate alone. The number of aphids per leaf in the derris-calcium arsenate-treated plots was 40 per cent less than in the calcium arsenate-treated plots, but plant injury was severe following both treatments. Pepper weevil control was about the same in all fields, in that calcium arsenate and 70-per cent cryolite were about equally effective and both significantly more effective than 50-per cent cryolite. Plants treated with calcium arsenate showed a typical kind of injury characterized by defoliation and pod shriveling, yet no injury of the same type was observed in cryolite-treated plots. Chemical injury to leaves was observed in calcium arsenate plots in some cases.

In comparing the effect of cryolite and calcium arsenate on the number of aphids per leaf with the degree of plant injury, several things are definitely shown (Table 3). Almost half the cryolite plots had less than six aphids per leaf, while all the calcium arsenate plots had more than six aphids per leaf. No definite plant injury occurred in any of the cryolite plots, while 80 per cent of the calcium arsenate plots

Table 3.—Number of aphids per leaf compared to degree of plant injury in three pepper fields following the use of various insecticide combinations for pepper weevil and aphid control. San Juan Capistrano, Calif. 1942.

Aphids per Leaf	Cryolite Plots					Calcium Arsenate Plots				
	Frequency	Plots Showing Various Degrees of Plant Injury[1]				Frequency	Plots Showing Various Degrees of Plant Injury[1]			
		1	2	3	4		1	2	3	4
Number	*Number*	*Number*				*Number*	*Number*			
1 to 5	77	77				0				
6	19	19				1			1	
7	18	18				1		1		
8	11	10	1			2	2			
9	13	10	3			2			2	
10	8	8				6		2	4	
11	4	4				4		1	3	
12	1	1				5		4	1	
13	2	2				5		1	4	
14	1	1				4			4	
15	1	1				6		1	5	
16	1	1				4			3	1
17 to 32	0	0				20		2	10	8
Total	156	152	4			60	2	12	37	9

[1] 1. No injury.
2. Heavy sooty mold fungus.
3. Definite plant injury, some defoliation and pod shriveling.
4. Severe plant injury, much defoliation and pod shriveling.

showed definite to severe plant injury. Moreover, as the number of aphids per leaf increased in the calcium arsenate plots, there was a definite tendency for the degree of injury to increase. From these data it would be possible to conclude that the aphids were entirely responsible for the damage in the calcium arsenate plots. However, previous data (Table 1) showed that certain cryolite and calcium arsenate plots with nearly the same aphid populations had these same differences in injury, so the damage and lower yield in the calcium arsenate plots can be attributed largely to insecticidal burning. With these conflicting data, it is safe to conclude only that calcium arsenate damaged the plants, and that this damage was most severe when the aphid populations were high.

SUMMARY.—The use of calcium arsenate to control the pepper weevil on peppers has caused increases in the aphid populations. Tests were made with aphicides in an attempt to prevent the aphid increase. In 1941, after the use of cryolite and one brand of calcium arsenate, alone and in combination with derris, the aphid population did not greatly increase in experimental plots, and no damage was caused, but in commercial fields in other areas where calcium arsenate or derris-calcium arsenate combinations were used there was a rapid increase of aphids and subsequent plant injury and defoliation. In 1942 calcium arsenate undiluted and 50- and 70-per cent cryolite were used alone and in combination with derris, pyrethrum, and free nicotine so that the final mixtures containined 0.5 per cent of rotenone, 0.1 per cent of total pyrethrins, and 1 per cent of nicotine, respectively. These materials were applied to three pepper fields, each arranged in six 3 by 4 randomized blocks. On the basis of percentage of pods infested by the pepper weevil there were no appreciable differences in the degree of effectiveness of 70-per cent cryolite and calcium arsenate, but each of these materials was more effective than 50-per cent cryolite. Aphids increased much less in the cryolite-treated plots than in the calcium arsenate-treated plots. The aphicide materials all had some effect in retarding aphid increase, but when they were used with calcium arsenate this retarding effect was not enough to prevent serious aphid infestations. Plant injury did not follow the use of cryolite, nor was it due to the aphids. There apparently is an interrelationship between the abundance of aphids and calcium arsenate. A marked aphid increase is likely to follow the use of calcium arsenate, and the combination of calcium arsenate and aphids causes plant injury to peppers.—6-28-43.

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A BIT OF ENTOMOLOGICAL HISTORY

Mr. A. F. Burgess, commenting on the obituary notice for Dr. Felt appearing in this issue of the *Journal* wrote, as follows: "At the ninth Annual Meeting of the Association August 1897, Dr. W. E. Britton, Dr. E. P. Felt and myself were among the active members elected. The tenth annual meeting was held in Boston and the three new members mentioned above attended and presented papers .... Throughout the years which followed it has been my privilege to know Dr. Felt and Dr. Britton and to understand the outstanding contributions which they made ...." We are indeed fortunate to have the obituary notice prepared by one who knew Dr. Felt so intimately and was able, better than any one else, to appreciate his services to the Association.

Studies on Body Fluids of Seven Orthopterans, Their pH, Buffering Capacity, and Effect on Solubility of Fractionated Insecticides[1]

ELLSWORTH HASTINGS and J. H. PEPPER, *Montana Agricultural Experiment Station, Bozeman*

The severe and widespread outbreaks of grasshoppers and Mormon crickets during the past decade have resulted in an enormous increase in the quantities of insecticides used for their control. A natural outgrowth of such a condition is a demand on the part of the control agencies involved for a more detailed knowledge of the specific actions and behaviors of the insecticides under the conditions in which they are normally employed. This situation resulted in the initiation of many short-time projects whose objectives were the obtaining of information which would have immediate appolication in field control operations. By their very nature these investigations could only be considered as preliminary, thus leaving many of the basic problems still unsolved. The question of the physico-chemical behavior of the active ingredients in a dust or in a bait, when such ingredients are employed in the solid or particulate forms, continues to be the subject of much discussion and is important both from the standpoint of effective control and cost of materials. It is a subject upon which only information of a fragmentary nature has been obtained.

Any insecticide, when used in the solid form, must first go into solution before it can become effective. Only in this state will it comply with the forces of diffusion, permeability, etc. which govern its movements into the various tissues of the insect. Once the insecticide is ingested by the insect, the problem then resolves itself to the factors affecting its solubility as it passes through the digestive tract. This problem divides itself into two parts, namely; that dealing with the solvent action of the digestive juices, and that having to do with the physical and chemical nature of the insecticide under study.

This work was instigated to obtain information relating to the solvent action of the digestive juices and to study the effects of one physical property of the insecticide, *vis;* that of particle size in relation to its solubility in the juice.

The first part of this paper will deal with studies made on the digestive juices obtained from several species of Orthoptera. The last part will concern itself with the relationship of particle size of several arsenicals as well as sodium fluosilicate to their solubilities in these juices.

The solubility of an insecticide may be markedly affected by the nature of the material in which it is being dissolved. Where the solvent is a pure substance its specific action alone will be the determining factor but when it contains other materials in solution, suspension, or in the colloidal state, its solvent action for a particular compound may be changed considerably. The acidity or alkalinity of a solvent is likewise known to have a marked effect on its behavior toward a given material.

In passing through the alimentary canal of both crickets and grasshoppers an insecticide will first come into contact with the digestive juices contained in the crop or fore gut. According to Wigglesworth (1934) in the case of Orthoptera the crop contains, in addition to salivary secretions, digestive juices which are passed forward from the mid-gut. In addition to these juices, the crop also contains partially digested food, various salts in solution (see Bishop *et al.* (1925), Swingle (1930), and Pepper *et al.* (1941)) as well as proteins and other colloidal materials. From the crop it passes into the mid-gut where further solution and absorption takes place.

One of the factors affecting the solubility of the insecticide in the alimentary tract would be the hydrogen ion concentration of the digestive juices. Working with a series of arsenicals Pepper & Green[2] (1934) found that each member of the entire series showed a minimum solubility in distilled water at its normal pH. This is the pH of a saturated solution of the arsenical in distilled water. They further found that the solubility increased very rapidly on either side of its normal

[1] Contribution from Dept. Zool. and Ent. No. 181 Mont. Agr. Exp. Sta., Bozeman, Montana.

[2] Unpublished data, Montana Agr. Expt. Sta., Bozeman, 1934.

pH when the arsenical was placed in a strongly buffered solution. Materials having an acid reaction became increasingly scluble as the buffered solution was made more basic, and those having a basic reaction became more soluble as the buffers were made more acid. Swingle (1938) found that the formation of soluble arsenic from acid lead arsenate, calcium arsenate, and magnesium arsenate was largely dependent on the hydrogen ion concentration of the solution. He further states that "it appears possible to predict the relative order of toxicity of acid lead arsenate, calcium arsenate, and magnesium arsenate to chewing insects, if the hydrogen ion concentrations in the insects' mid-guts are known."

Skrjabina (1936) found that varying toxic effects of certain insecticides could be theoretically accounted for by the fact that for different pH values there occur differences in solubility, degree of dissociation, hydrolysis and other properties of the material.

Marshall (1939) points out that the acid or basic characteristics of the internal environment of the codling moth larva may have a practical bearing on the control of the insect by alimentary poisons.

A measure of the normal reaction of the digestive juices may then serve as a valuable index of their power to dissolve a given insecticide. A measure of the normal pH alone, however, is of limited value since it gives no indication of the solution's power to resist changes in reaction upon the addition of either an acid or a basic substance. A measure of its buffering capacity, which is a measure of its power to resist changes in pH, will furnish the required data. In a similar way such data on the blood of an insect will reveal its power to withstand changes in pH when small amounts of acid or basic substances come in contact with it. Preliminary experiments have demonstrated that when micro-injections of very dilute acid or base are made into the blood stream of the Mormon cricket, death results immediately.

Hoskins & Harrison (1934) measured the reaction and buffering capacity of the contents of the ventriculus of the honeybee. They found the normal pH to be 6.3 and that maximum β values of approximately 0.095 and 0.03 occurred at pH values of 4.15 and 6.8 respectively. Craig & Clark (1938) measured the normal pH and buffering value of the blood of larvae of *Pieris rapae* (L.) and *Heliothis obsoleta* (F.). They found that the caterpillars in the last instar gave a definitely more alkaline reaction than those in the next earlier instar, the values being 7.17 for the last instar and 6.9 for those next to the last instar in *Pieris*, and 7.23 and 6.79 for the comparable stages in *Heliothis*. They further state that no single definite buffer system was evident on the buffer value curves but that a general buffer effect was shown in the region of pH 4 to 7.5, which they suggest was probably due to the composite effect of the salt buffers of this range, and the plasma proteins.

Babers (1941) measured the buffer capacity of the blood of the sixth instar southern armyworm, *Prodenia eridania* (Cram.), and found a β value of 0.022 at pH 6.65, the normal reaction of the blood. He attributed the buffering power of the blood to the presence of bicarbonates, phosphates, urates, and salts of the proteins, as well as the phosphorous-containing organic compounds and the amino acids (Babers 1938).

Pepper *et al.* (1941) studied the buffering capacity of the blood and digestive juices of the Mormon cricket, *Anabrus simplex* (Hald). and concluded that at neither the normal pH of the blood, 7.23, nor of the digestive juices, pH 5.17, was a maximum value for β evident. They found that both the blood and the digestive juices had low buffering indices at their normal pH values and could not designate any particular buffer system as being responsible for the effects shown.

In the present study six species of grasshoppers, namely, *Melanoplus bivittatus* (Say), *M. mexicanus* (Sauss.), *M. differentialis* (Thom.), *M. packardi* (Sc.), *Dissosteira carolina* (L.), and *Brachystola magna* (Gir.) are included. Isely (1938) has shown that many species of grasshoppers have very definite host preferences and further, that many of them cannot even subsist on green vegetation other than within their limited host range. Such a condition leads to the belief that differences might occur in the reaction of the digestive juices in the various species. For this reason *B. magna*, whose preferred hosts differ widely from those of the other five species, was included in the study.

Both the blood and the regurgitated

digestive juices were collected in a manner similar to that described by Pepper *et al.* (1941). This material was obtained by holding a small vial under the mouth parts and collecting the regurgitated contents.

For the pH and buffering capacity determinations approximately 3 ml. of juice were collected, centrifuged in order to remove any solids which might be present, and the measurements made immediately on 2 ml. portions using a Cameron pH meter with a semi-micro glass electrode. All of the determinations were made in duplicate.

The blood was obtained from the adult grasshoppers by puncturing the dorsal intersegmental membrane and collecting the exuded drops in a capillary tube. Approximately 3 ml. were thus collected and centrifuged to remove the clots and a 2 ml. portion of the serum used for the determinations which were made in duplicate. As was pointed out by Pepper *et al.* (1941) this method of handling the blood does not result in any perceptible change in its reaction during the interval in which the determinations are being made.

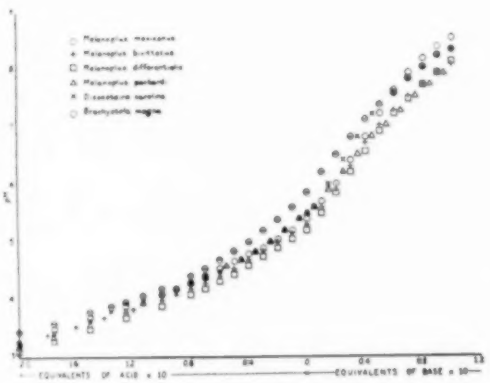

FIG. 1.—Titration curves for the regurgitated digestive juice of the species of grasshoppers listed.

The titrations were carried out using 0.1 *N* HCl and KOH. The titration curves for the regurgitated digestive juices of the six species of grasshoppers are shown in figure, 1, and for the blood in figure 2.

The buffering capacity or β values of the fluids were obtained by the method of Van Slyke (1922) which consists of plotting the titration curves on cross section paper, using as large units as possible, and then drawing tangents to selected points on the curves. The slope of the tangents, $(dB/d\ \text{pH})$ or $(dA/d\ \text{pH})$, where B and A are equivalents of base and acid per liter respectively, were then determined. These are designated as the β values and

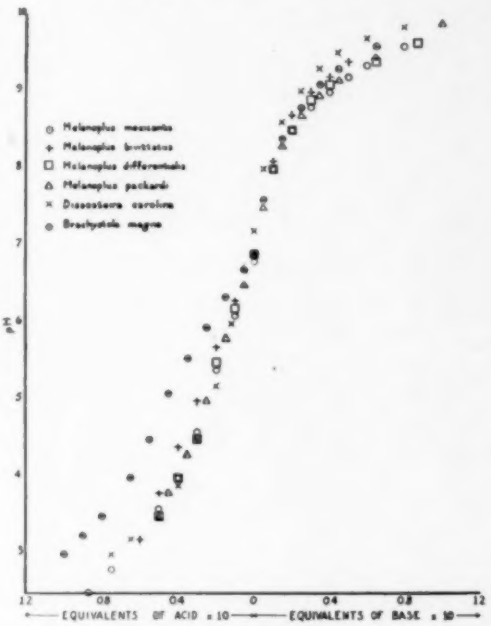

FIG. 2.—Titration curves for the blood serum of the species of grasshoppers listed.

are a direct measure of the buffering capacity of the system under study, i.e. the buffering capacity increases as β values approach unity. These values of β with their corresponding pH are shown for the regurgitated digestive juices in Fig. 3, and for the blood serum in Fig. 4.

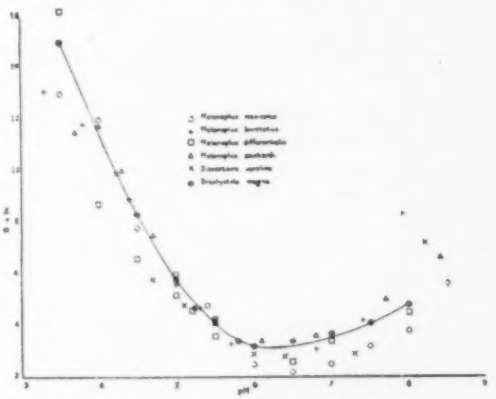

FIG. 3.—Buffering capacity curves for the digestive juices of the species of grasshoppers listed.

It will be noted that a considerable similarity exists for all species studied, not only in the normal pH of the regurgitated digestive juices and of the blood, but also in the general shape of their titration

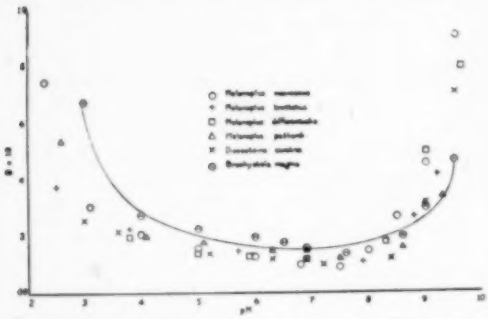

FIG. 4—Buffering capacity curves for the blood serum of the species of grasshoppers listed.

curves. This fact is further emphasized in figures 3 and 4 where the slope of the curves are plotted against their corresponding pH values. The normal pH and the corresponding β values for the fluids of the six species of grasshoppers are shown in table 1.

Table 1.—The normal pH and corresponding β value of the regurgiated digestive juices and blood of six species of grasshoppers.

	Regurgitated Digestive Juice		Blood	
Species	pH	β	pH	β
Melanoplus mexicanus	5.4	.048	6.8	.010
bivittatus	5.3	.047	6.9	.012
differentialis	5.2	.046	6.9	.012
packardi	5.5	.041	6.9	.015
Dissosteira carolina	5.5	.042	7.2	.010
Brachystola magna	5.8	.034	6.9	.016

In no case would one be justified in concluding that any appreciable difference between the species existed in either the normal reaction or in the behavior of their fluids toward acid or basic substances. It should be kept in mind that any handling of the insects is abnormal and such handling prior to and during the extraction of the fluids could, and very likely would result in a slight change from the normal reaction. This could very easily account for the variations noted.

The regurgitated digestive juices are poorly buffered in the vicinity of their normal pH and do not show any appreciable buffering qualities until they are removed 1.5 to 2 pH units on either side of their normal reactions. In view of these findings one would not expect that any insecticide, the normal pH of which lies between 4 and 8, would have its solubility greatly affected by the reaction of the digestive juices. However, if the normal pH of the insecticide lies on either side of the above range, its solubility could be markedly affected by the reaction of the grasshopper juices studied.

In the case of the blood, the interest is not in its effect on an insecticide but rather on the latter's effect on the blood's normal reaction. It was found that the grasshopper blood was very poorly buffered at its normal pH and further that it continued to be poorly buffered for several units on either side of this normal value. One would then suspect that any material possessing fairly strong acid or basic properties, which was able to enter the blood stream of these insects, could have a pronounced effect on the blood reaction. Since the indications are that the Mormon cricket, at least, is extremely susceptible to slight changes in the pH of its blood, it is not beyond the realm of possibility that considerable toxic affect may be exerted by insecticides on the blood due to their acid or basic reactions.

The above discussion on solubility does not take into account the probable effects of varying particle size, the salt type and concentration present in the digestive juices, or the effect of proteins and other materials present in it. Theoretically the rate of solubility of the insecticide should be, within limits, inversely proportional to its particle size. Consequently the smaller particles should exhibit greater toxic effect than the larger ones since the insecticide remains in the digestive tract for only a limited time. It is probable then that equilibrium solubility conditions are never reached so that the speed at which the material is dissolved would be the deciding factor in its effectiveness. The above does not always appear to be the case as Siegler & Goodhue (1939) working with different fractions of four arsenicals and phenothiazine found that except for phenothiazine no great difference in toxicity of the different fractions was obtained when tested on codling moth larvae. In

general, however, they found that for the arsenicals the medium fraction (5–10 microns) was slightly superior to either the fine (2–3 microns) or the coarse (18–29 microns) fractions. With phenothiazine they found the coarse fraction (45 microns) to be less toxic than either the medium (15 microns) or fine (4 microns) fractions.

McGovran *et al.* (1940) fractionated paris green and tested the different fractions against the Mexican bean beetle (*Epilachna varivestis* Muls.). They obtained the greatest mortality with particles having an average diameter of 1.1 microns followed in order by those having an average diameter of 12 and 22 microns.

Cowan & Hinman[1] (1940) fractionated sodium fluosilicate into three fractions and tested their toxicity on the migratory *Melanoplus mexicanus* (Sauss.). They found that, within limits, toxicity was directly proportional to particle size.

It appears then that a direct relationship does not always exist between particle size and toxicity of the insecticide, and further that the variations may be due to either or both the character of the insecticide and of the digestive juices of the test insect.

The upper limit of size of a particle showing colloidal properties has been arbitrarily set at 0.5 of a micron in diameter. However, the particles of an emulsion which show strong surface properties are well above this limit. It is quite reasonable to suppose, then, that the smaller particles of an insecticide (2 to 5 microns) exhibit surface properties which cause them to react differently in the digestive juices than is commonly postulated. Charges may be adsorbed from the surrounding media which would result in the particles presenting an unwettable surface to the juices and thus prevent their solution, or they may adsorb proteins onto their surfaces thus forming a protective coating and consequently inhibiting solution.

The effect of the salt type and concentration present in the juices may also be a contributing factor to abnormal solubility behavior. In any event it appears as though a study of the individual behaviors of the different insecticides in the actual medium in which they must dissolve, in order to become effective, will be necessary before conclusive data can be obtained on this problem.

In the present study an attempt was made to find what differences, if any, existed between the rates of solubility of various fractions of arsenious oxide, sodium arsenite, and sodium fluosilicate in both distilled water and in the regurgitated digestive juices from two species of grasshoppers and from Mormon crickets.

C. P. arsenious oxide was fractionated by screening into five uniform fractions having average particle diameters, as determined by a stage micrometer, of 3, 9, 20, and 32 microns. The fractions of sodium arsenite had average particle diameters of 3, 8, and 16 microns, and of sodium fluosilicate 6, 26, and 51. The fractions of sodium arsenite and sodium fluosilicate were obtained from commercial products and upon analysis were found to contain uniform arsenious oxide and fluorine content respectively. Also included in the study were unfractionated commercial samples of standard paris green, air float paris green, and lead arsenate.

The relative rates of solubility were determined as follows: One hundred mg. each of the arsenicals and sodium fluosilicate were placed in vials with five ml. of the digestive juice or distilled water for the arsenicals and 10 ml. for the fluosilicate. The vials were tightly stoppered, placed in a water bath at 32° C. for 24 hours, and vigorously shaken at hourly intervals for the first eight hours. Their contents were then filtered through a fine grade of filter paper and an aliquot of the filtrate used for the analysis. Arsenic was determined by the micro method of Cassil & Wichmann (1939) and fluorine by a modification of the method of Willard & Winter (1933), and Reynolds *et al.* (1936).

The solubilities as determined by the above method are only relative and should not be construed as being the true equilibrium solubility of the material studied. Extreme variations in the rate of solution may be encountered with such materials as the fine fractions of arsenious oxide, paris green, etc. which are only wetted with difficulty.

The average of duplicate determinations for the arsenicals are shown in table 2. The arsenious oxide was considerably more soluble in distilled water than in the digestive juices, the solubility in water de-

[1] Unpublished data, U.S.D.A., Bureau of Ent. & Plt. Quar., Bozeman, Montana.

creasing markedly as the particle size increased from 3 to 32 microns. This is likewise the case in the digestive juices of both *Brachystola magna* and *Anabrus simplex* but to a much lesser extent, the difference in solubility between particles having an average diameter of 3 and 32 microns being only 3.22 and 0.83 mg. for the juices as compared with 16.92 mg. for the same range in distilled water. The decrease in solubility in the digestive juices shows them to have some marked inhibitory effect on the solubility of arsenious oxide.

Table 2.—Solubilities of various samples of arsenicals in distilled water and in digestive juices of the lubber grasshopper and the Mormon cricket.

Material	Ave. Particle Dia. in Microns	Mg. As_2O_3 Recovered from 100 mg. of Arsenical Suspended in 5 ml. Water or Juice		
			Digestive juices	
		Dist. water	B. magna	A. simplex
Arsenious oxide	3	19.36	5.24	0.93
	9	8.26	3.34	0.37
	20	5.51	2.52	0.21
	32	2.44	2.02	0.10
Sodium arsenite	3	100.0	100.0	—
	8	100.0	92.0	—
	16	100.0	78.5	—
Paris green				
Standard	—	0.73	30.66	—
Air float	—	0.74	57.70	—
Lead arsenate	—	0.04	0.91	—

A similar situation prevails with sodium arsenite except that the effect is much less pronounced.

With paris green the situation is just reversed, this material being markedly more soluble in the digestive juices than in the distilled water. There is likewise an increase in solubility in the juice with the air float paris green, which is a very finely divided product as compared with the standard material. Toxicity tests against the sugar beet webworm, *Loxostege sticticalis* L., made by this department, have shown the air float to be approximately 10 per cent more toxic than the standard product.

Lead arsenate was likewise more soluble in the digestive juices of *Brachystola magna* than in distilled water. However, the difference in mg. of material dissolved is relatively small compared with that of paris green.

The pH of a saturated solution of the above materials is as follows: Arsenious oxide 6.1, lead arsenate 5.8, paris green 6.2, and sodium arsenite 10.3. With the exception of sodium arsenite the normal pHs of these materials all lie within the zone in which the digestive juices are the most poorly buffered. In view of the points brought out in previous discussion one would not suspect that any of these arsenicals, with the possible exception of sodium arsenite, would be affected to any extent by the reaction of the digestive juices. Sodium arsenite is highly soluble in both acids and bases so that the pH of the solution would have little, if any, effect on its solubility.

The large increase in the solubility of paris green in the digestive juices over that in distilled water can be accounted for, possibly, by the presence of certain salts in the juices which react with the paris green in such a way as to render it more soluble, or by some properties of the juices which might increase their wetting powers.

The fluorine was determined as follows: To an 8.0 ml. aliquot of the previously described filtrate, 2.5 ml. of a 10 per cent solution of magnesium nitrate were added and the solution slowly evaporated on a hot plate, care being taken to prevent excessive foaming. It was allowed to remain on the hot plate until ignition had taken place and all action had ceased, after which it was ashed at 450° C. for five hours. The ash was then transferred to a distilling bulb and 5 ml. of distilled water and 10 ml. of 60 per cent perchloric acid added to it. Steam distillation was then carried out at 139° C. until 150 ml. of distillate had been collected. A distillation apparatus similar to that described by Reynolds *et al.* (1936) was used, the required temperature being maintained by the use of tetrachloroethane. The distillate was then neutralized with 1.0 *M.* sodium hydroxide using phenolphthalein as an indicator, and the volume made up to 250 ml. with distilled water.

To a 50 ml. aliquot of this solution five drops of alizarin indicator (0.1 per cent aqueous solution of sodium alizarin sulfonate) were added and 0.1 *M* hydro-

chloric acid added until the pink of the alizarin was discharged. To this was added 2.5 ml. of buffer solution prepared by neutralizing to phenolphthalein 200 ml. of 1.0 *M* monochloroacetic acid with potassium hydroxide, adding to the neutralized solution 200 ml. of the 1.0 *M* chloroacetic acid and diluting to one liter. The solution was then titrated with 0.04 *N* thorium nitrate. The end point is not very sharp and requires considerable practice in order to obtain exact duplications.

The results of the fluorine analysis are shown in table 3.

Table 3.—Solubilities of fractionated sodium fluosilicate in distilled water and in digestive juices of the Mormon cricket and the two-striped grasshopper.

Ave. Particle Dia. in Microns	Mg. Sodium Fluosilicate Recovered from 100 mg. of this Material Suspended in 10 cc. of Water or Juice		
		Digestive juices	
	Distilled water	A. simplex	M. bivittatus
6	78.4	29.0	10.1
24	70.3	28.8	8.9
56	61.7	23.8	8.1

The difference in solubility in relation to particle size in distilled water is not so great as one would expect considering the large differences in the average particle diameter. There is practically no difference in the solubility in cricket digestive juices between particles, the average diameters of which are 6 and 24 microns respectively, and only a small difference between the above two and those having an average particle diameter of 56 microns.

Sodium fluosilicate is only about 35 per cent as soluble in the digestive juices of the two-striped grasshopper as in those juices of the Mormon cricket and shows no appreciable change with particle size. This difference might be accounted for by differences in the composition of the digestive juices in the two species. The normal reactions of the digestive juices are pH 5.3 for *Melanoplus bivittatus* and pH 5.2 for *Anabrus simplex* (Pepper *et al.* 1941) and they are both poorly buffered in this vicinity. Since the pH of a saturated solution of the sodium fluosilicate used in these experiments was 4.2, one would not expect the pH of the juices to have any appreciable effect on the solubility of this compound. The differences in solubility then must be due to other physico-chemical properties of the juices.

While the above experiments serve to point out differences in the solubility behavior of the digestive juices from different species of insects they still leave many questions to be answered. The large differences encountered in almost every case between the solubility of the insecticide in water and in the digestive juices of the insect show that the water content of the juices may have a pronounced effect on their solution properties. Such a condition would in turn be governed by the type of food ingested by the insects just prior to and during the period in which the insecticide was present in the alimentary tract. Other factors such as rainfall and dew would also have their effect on the water content of the juices. It may well be that highly significant differences in the solubility of a stomach poison could be encountered in the digestive juices within the same species of insect when they were feeding on different host plants or on the same host plant in different stages of development.

The removal of all solid matter from the digestive juices in the above experiments would also produce a condition which is not comparable to that under which the actual poisoning operations take place.

SUMMARY.—The normal pH of the regurgitated digestive juices from six species of grasshoppers, viz. *Melanoplus mexicanus*, *M. bivittatus*, *M. differentialis*, *M. packardi*, *Dissosteira carolina*, and *Brachystola magna*, were determined. They all fell within the pH range 5.2 to 5.8.

Titration curves were obtained on the above digestive juices and from such curves the buffering capacities or β values were determined. All of the juices were poorly buffered at their normal reaction as well as for a range of approximately 1.5 pH units on either side of this value.

The normal pHs of the blood sera were also determined for the above species of grasshoppers and they all fell within the range pH 6.8 to 7.2. Titration curves were also obtained for these fluids and their β values determined. The blood of the species of grasshoppers studied was very poorly buffered both at and in the vicinity of its normal pH.

The solubilities of fractionated samples of arsenious oxide, sodium arsenite, and sodium fluosilicate were studied in distilled water and in the digestive juices of the Mormon cricket, *Arabrus simplex*, and in that of two species of grasshoppers, viz. *Brachystola magna* and *Melanoplus bivittatus*. With distilled water, in every case the solubility decreased as the particle size increased. In the digestive juices this same general trend was observed but it was not nearly so pronounced. The solubilities of arsenious oxide and sodium fluosilicate were considerably less in the digestive juices than in distilled water.

Commercial paris green was over 50 per cent and air float paris green over 85 per cent more soluble in the digestive juices of *Brachystola magna* than in distilled water. This was also the trend with commercial lead arsenate but to a lesser extent.—6-16-43.

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Experiments for Field Control of the Narcissus Bulb Fly

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The narcissus bulb fly, *Lampetia equestris* (F.), is the major insect problem confronting narcissus bulb growers in the Pacific Northwest. Infestation develops in the bulbs from eggs deposited approximately at the soil surface during May and June. The normal time for digging the bulbs comes a month or 6 weeks after the fly larvae start feeding within the bulbs. Hence treatments of the bulbs after digging can be only partially effective, since considerable damage has already occurred. It has been recognized that the most effective type of treatment would be a method which would prevent actual attack of the bulbs.

Research on the narcissus bulb fly was initiated by the United States Department of Agriculture in the Pacific Northwest in 1927. A number of materials and combinations were applied to bulb plants in the field during the first few years of this project, but favorable indications obtained were very meager. There were some indications that applications of hydrated lime were effecting some reduction in infestation. This material was tested on a semi-commercial scale in 1936. Applica-

tions were made to 6 blocks in one field and 4 blocks in a second field, using 5 pounds of hydrated lime to 50 feet of bulb row. In the first field the infestation in the treated areas was less than in untreated areas, while in the second field the lime-treated areas were found to have a higher infestation than the untreated areas.

Starting in 1938, a number of materials were tested in small field plots arranged either in randomized blocks or latin squares. Of the materials tested, the best results were obtained with an inverted spray mixture recommended by Marshall & Groves (1938) for codling moth control as W.S.C. "dynamite," which is a lead arsenate-mineral oil emulsion. The use of the following materials resulted in significant reductions in the numbers of infested bulbs as compared with the untreated lots:

Material	Relative Control (Per Cent)
Lead arsenate-mineral oil (W.S.C. dynamite formula)	81**
Mineral oil emulsion (5%)	76**
Naphthalene flakes	63**
Dichloroethyl ether and hydrated lime (dust)	54**
Cube dust (0.5% rotenone)	50**
Calomel (suspension)	45**
Mercuric chloride solution	41**
Naphthalene sulfur, and hydrated lime (dust)	38**
Sodium fluosilicate (1 lb. to 4 gal. water)	35*
Sulfur (dust)	32*
Hydrated lime (dust)	26*

** Highly significant reduction in infestation ($P = 1$ per cent).
* Significant reduction in infestation ($P = 5$ per cent).

Several materials that were tried did not yield significant results under the conditions of the tests. This does not mean that they are necessarily removed from consideration in future investigations, because further study may develop favorable information concerning their use. These materials are as follows:

Liquid applications:
- Amyl acetate
- Bordeaux mixture
- Di-butyl-phthalate
- Ethylene dichloride
- Ethyl mercury chloride
- Isopropyl formate
- Lignin pitch (paper mill byproduct)
- Lime-sulfur
- Nicotine tannate
- Phenothiazine (ordinary and micronized)
- Sodium cyanide
- Xanthone

Dust applications:
- Copper carbonate
- Cryolite
- Nicotine and bentonite
- Nicotine peat
- Phenothiazine and bentonite
- Sodium fluoride and bentonite

Miscellaneous oils were tested as 1 per cent emulsions in comparison with mineral oil emulsion of similar strength. The results obtained with these were not statistically significant, but further tests are considered advisable for some of these oils.

- Castor oil (U.S.P. grade)
- Castor oil (sulfonated)
- Coconut oil
- Cottonseed oil
- Fish oil
- Peanut oil
- Pine oil
- Rapeseed oil

In view of the apparent effectiveness of a ground cube root dust containing 0.5 per cent rotenone, further tests with this type of material were made. Both liquid and dust applications were tried. These are listed below with the relative control obtained.

Material and strength	Relative Control (Per Cent)
Cube root, blown castor oil, liquid application, rotenone 1–5000	28
Cube root, dusting sulfur, 1.0 per cent rotenone, dust application	25
Cube root, pine oil, liquid application, rotenone 1–5000	16
Cube root, bentonite, 1.0 per cent rotenone, dust application	14
Cube root, bentonite, 2 per cent pine oil, 1.0 per cent rotenone, dust application	6
Cube root, bentonite, 1.0 per cent rotenone, dust application	6
Cube root, water suspension with Vatsol OS, rotenone 1–5000, liquid application	−1.5
Cube root, coconut oil, liquid application, rotenone 1–5000	−6
Cube root, bentonite, 0.5 per cent rotenone, dust application	−13

In these tests the rates of application were such that the amount of rotenone applied in the liquid applications was equivalent to that applied in dust applications with 0.5 per cent of rotenone. These tests indicate that this rotenone-bearing material is not appreciably effective in controlling the narcissus bulb fly.

One test with a dust composed of hydrated lime impregnated with dichloroethyl ether gave a promising degree of

control (54 per cent). When equivalent amounts of dichloroethyl ether were used in water (12 cc. per gallon) no effect was indicated in 2 tests, one producing 3 per cent, the other −7 per cent relative control.

Because of the very favorable indications obtained in the first tests with the "W.S.C. dynamite" formula and mineral oil emulsion, tests with these materials have been expanded in order to determine more positively the possibilities of their use. The "dynamite" formula was broken down, and the several ingredients were tested in 2 series. In the one the materials were tested by omission, in the other they were used separately. The results are shown in table 1.

Table 1.—Effectiveness of various ingredients of the "W.S.C. dynamite" formula for field control of the narcissus bulb fly.

	Material Tested	Relative Control, Per Cent
A	Complete "dynamite" formula	71**
B	Mineral oil, triethanolamine, and oleic acid (lead arsenate omitted, 1% oil)	44**
C	Lead arsenate, triethanolamine, and oleic acid (mineral oil omitted)	30**
D	Mineral oil and lead arsenate (triethanolamine and oleic acid omitted)	52**
E	Untreated check	—
F	Complete "dynamite" formula	62**
G	Mineral oil emulsified with Vatsol OS	58**
H	Triethanolamine and oleic acid	19
I	Lead arsenate	−37*
J	Untreated check	—

* Significant at 5 per cent level.
** Significant at 1 per cent level.

These tests indicate that the effectiveness is associated primarily with the oil ingredient, and that there may be a slight advantage for the complete formula over the oil. The difference between A and B has statistical significance, but there is none for the difference between F and G. The significance of the increased infestation where lead arsenate alone was used is of interest. The data are insufficient to furnish an explanation of this effect.

The "dynamite" formula has also been tested with variations of the proportions of oil and lead arsenate used. Oil concentrations of none, 0.5, 1, and 2 per cent were tested without lead arsenate and with dosages of 3 and 6 pounds of lead arsenate per 100 gallons. The concentration of lead arsenate had very little effect upon the bulb fly infestation, whereas the concentration of oil had a marked effect. In comparison with infestation in the plots treated with the oil-less spray there were reductions of 20, 56, and 61 per cent by the inclusion of 0.5, 1, and 2 per cent of oil, respectively, in the spray. The latter two reductions are significant.

Experiments have been made to compare a light summer oil with a heavier dormant-season oil, and with varying amounts of oil. These tests have not produced significant results as far as infestation is concerned. The heavier type of oil was tolerated by the plants slightly less than the light oil, and indications of possible lack of tolerance were observed where the lighter oil was used at a concentration of 4 per cent. Further experiments are needed to determine these phases.

Mineral oil emulsions have been tried on a semi-commercial scale in three narcissus plantings, using growers' spraying equipment adjusted to apply the materials at the bases of the plants. A 1 per cent emulsion of a light summer spray oil was used in these tests, and randomized block arrangements were followed. Two of the plantings were of considerable size, and the infestation was relatively low. The third planting was small. Samples were selected from the central portions of all plots. In the treated plots in planting A the infestation was reduced 48 per cent, in planting B the infestation was reduced 81 per cent, and in planting C the reduction was 55 per cent, as compared with untreated plots. Analysis indicated that these reductions were highly significant.

Naphthalene produced favorable results when tested in a preliminary way, and this material has been tested further. Refined naphthalene flakes have been used throughout, because crude naphthalene injured the narcissus foliage in preliminary tolerance tests. No injury from the refined material has been observed. A test was made in a randomized block design to determine the amount of material to be used. Four dosages were compared, namely, 0.5, 1.0, 1.5, and 2.0 pounds to 100 feet of bulb row. With the 0.5-pound dosage no control was evidenced. The 1-pound rate produced a 48 per cent reduction, the 1.5-pound rate produced a 69 per cent reduction, and the

2-pound rate gave a 59 per cent reduction. Analysis indicated that these control results were significant, but indicated no significant differences between the 3 rates of application.

In an experiment planned to determine the optimum time for application of naphthalene, variation in infestation was excessive, and no significance was indicated by analysis of the results, although some reduction of infestation was associated with all dates of application.

Naphthalene was tested on potted narcissus bulbs in a greenhouse to determine the duration of effectiveness and nature of action. Five bulbs were grown in each pot, and naphthalene flakes were applied to the surface soil at a rate approximately equivalent to the field application of 1 pound per 100 feet of row. Eggs of the narcissus bulb fly were placed at the neck of each bulb at various intervals following the application of the material. The experiment followed a latin square design. The results are given in table 2.

Table 2.—Duration of effectiveness of naphthalene applied to soil surface for control of narcissus bulb fly in narcissus bulbs.

DAYS BETWEEN APPLICATION AND EGG PLACEMENT	NUMBER OF INFESTED BULBS
0	0
5	0
10	0
16	7
27	12
Check	14

Effectiveness is indicated for this material for a period of at least 10 days. The test indicates that the naphthalene has a lethal action against either the egg or newly hatched larva, and that effectiveness is not necessarily due to a repellent action against ovipositing adult flies.

It is recognized that a number of factors must still be determined before general recommendations can be considered for the use of any of these materials commercially. The utilization of randomized block arrangements makes it possible to compare various materials, and valuable information is obtained in this type of test. Practical application involves the use of materials on entire plantings, and evaluation of results under such conditions is difficult.

PLANT TOLERANCE.—Numerous samples of narcissus bulbs treated with the various materials which have been considered promising have been forced in a greenhouse during the season following treatment. In no case has there been any evidence of any detrimental effect on the flowering performance which could be associated with the application of a material the preceding season.

SUMMARY.—Experiments have been conducted in the Pacific Northwest to develop methods of preventing infestation of narcissus bulbs by larvae of the narcissus bulb fly. Numerous materials have been tested in plots arranged in randomized blocks or latin squares. A lead arsenate-mineral oil combination known as "W.S.C. dynamite," mineral oil emulsion, and refined naphthalene flakes have furnished very promising results. Tests of the ingredients of the "dynamite" formula indicate that the oil content may be largely responsible for the effectiveness of the mixture, and also indicated that lead arsenate alone may cause increased infestation. Extended tests with hydrated lime and with ground cube root indicate that these materials probably have no practical effectiveness. Laboratory tests with naphthalene demonstrate that it has a lethal action against the eggs and newly hatched larvae. The tolerance of the narcissus plants to these favorable materials has been satisfactory.—7-1-43.

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Productivity of the California Red Scale on Lemon Fruits

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The productivity of the California red scale, *Aonidiella aurantii* (Mask.), was observed in a citrus grove to obtain information on the rate of population increase following fumigation. Previous observations on the reproduction of this scale in southern California have been reported by Quayle (1911), by Bliss *et al.* (1931), and by Nel (1933), but since those studies were made under artificial laboratory conditions or were for a period of only several months, they did not give an adequate understanding of what takes place under field conditions. In this investigation the number of crawlers settling from each female scale and the length of the reproductive period were determined in the field throughout a year. Information was also obtained concerning the number of female crawlers reaching the mature stage. The field studies were supplemented with laboratory studies to provide additional records under controlled conditions.

FIELD STUDIES.—The field studies were conducted in a lemon grove south of Corona, Calif., in a locality where red scales are relatively difficult to kill by fumigation with hydrocyanic acid gas. The observations were begun in the spring of 1935 and were discontinued in the summer of 1936 after scales that began reproduction during each month throughout the year had been observed. All the scales except one adult female that had not started to reproduce were removed from a number of lemons on all sides of very lightly infested trees, and the productivity of the one remaining scale was estimated by counting the number of scales that settled on the fruit. The developmental stage of each young scale was recorded when the count was made. Crawlers that died before settling were not included.

The scales that were selected for reproduction were encircled with black waterproof ink and identified by number. Two cotton bands were placed around the stem of the lemon, one close to it and the other about 6 inches away, to prevent crawlers from other sources crawling onto the fruit as well as to restrict the young from the one reproducing scale on this fruit. Surrounding foliage and twigs that might touch the lemon were removed. At the beginning of the studies the host lemons were enclosed in muslin cages to prevent crawlers from other sources getting onto the fruits, but this proved unnecessary on very lightly infested trees. The fruits remained attached to the trees for the duration of the record, or until it was necessary to remove them either because they were about to drop or because the trees were to be given commercial treatment. The detached fruits were placed on half-pint milk bottles filled with water and held in the shade.

The fruits containing the reproducing scales were examined once a week with the aid of a hand lens while they were attached to the tree and with a binocular microscope when removed from the tree. The approximate dates of appearance of the first offspring, of the maturity of the female offspring, and of the death of each reproducing scale were recorded. Since there was no record of the last offspring produced by each scale, and production may have ceased some time before the reproducing scales died, the reproductive period was the interval over which crawlers may have been born. When a scale reproduced over an especially long period, the fruits occasionally spoiled, and the records had to be discontinued before the scale died.

The study included four groups of scales selected at different times so that one group began reproduction in the spring and early summer, another in the midsummer, the third in the late summer and fall, and the fourth in the winter and subsequent early spring.

Temperature and relative humidity records were obtained throughout the study with a hygrothermograph in a standard instrument shelter located in the grove.

The data on the productivity of the four groups of mother scales are summarized in table 1.

The second group of scales showed a high average daily production rate in July and August, the rate, in general, decreasing as the length of the reproductive period increased and as the temperature decreased. Most scales with a short re-

Table 1.—Reproduction records for groups of California red scales on lemon fruits in a lemon grove near Corona, Calif.

Group	Period Reproduction Began	Reproducing Scales	Reproductive Period			Date 50 Per Cent of Scales Completed Reproduction	Progeny Settled per Reproducing Scale		
			Range	Average	For 50 Per Cent of Scales		Range	Average	Daily Average
		Number	*Days*	*Days*	*Days*		*Number*	*Number*	*Number*
1	April 26–June 14, 1935	33	7–154	64.5	56	Aug. 2	5–300	153.4	2.4
2	July 19–Aug. 23, 1935	50	7–245	85.3	84	Nov. 1	13–294	158.5	1.9
3	Aug. 23–Oct. 11, 1935	69	7–287	154.3	182	Mar. 13	8–192	99.5	.6
4	Nov. 15, 1935–Feb. 28, 1936	18	14–245	145.1	147	May 15	2–171	65.6	.4
	March–May, 1936	24	35–119	77.0	84	June 10	7–221	93.2	1.2

productive period showed a high daily rate of production. For example, one record began on August 2 and ended on September 13, with 175 progeny in 42 days, averaging 4.2 per day; another began on July 26 and ended on September 6, with 163 progeny in 42 days, averaging 3.9 per day. Since many of the scales continued to produce into the winter, the average daily production for this group was reduced.

The records for the third group indicated that many of the mother scales produced young in the fall and also in the following spring.

The scales in the fourth group were selected late in October. Some of these scales began to reproduce during the winter months but others not until late in the spring. Reproduction that began from November to the end of February was restricted to scales in sun-exposed pockets in the foliage on the south, southeast, and east aspects of the trees, but these scales differed decidedly, both in length of the reproductive period and in total productivity, from those that began to reproduce in March, April, and May. Records for the scales that began to reproduce during each of these periods are shown separately in table 1.

In table 2 the productivity of the scales is summarized according to the month in which reproduction started. Scales began to reproduce during every month of the year. The scales that began in June averaged the largest number of offspring. These scales also completed production in the shortest time, if the occasional records for April 1935 and May 1936 are excluded. During the fall and winter months the length of the reproductive period increased and the number of offspring decreased. In other words, the mother scales whose entire production took place during the warm summer months had the highest production rate, and although production occurred during the winter months the rate was greatly reduced. The records for certain of the winter months are not very reliable owing to the small number of scales involved, but they show that production occurred throughout the year. With one exception, the scales that began to reproduce in the spring of 1936 were fertilized the previous fall and passed the winter in the mature stage.

Records on the development of the progeny of some of the scales in each group are summarized in table 3. In most instances not all the offspring of a scale had reached maturity by the time the final count was made; therefore, these records are incomplete. Since the sexes did not become distinguishable until midway in the second stage, progeny that had not attained that stage of development at the time of the final count were recorded as being of unknown sex. Female scales were designated as mature following fertilization. The number of empty male covers was assumed to indicate the number of males that had emerged and was determined when the final count of the progeny was made.

Table 2.—Productivity of California red scales in the field, summarized according to the month reproduction began.

Month Reproduction Began	Average Daily Temperature	Total Reproducing Scales	Average Length of Reproductive Period	Average Settling Progeny per Mother Scale
1935	°F.	*Number*	*Days*	*Number*
April	57.1	1	42.0	55.0
May	60.1	17	65.9	145.1
June	67.2	15	63.9	169.5
July	72.3	10	81.9	151.5
August	73.5	53	108.0	153.4
September	67.1	45	146.4	96.5
October	60.2	11	161.6	72.9
November	51.1	4	197.8	75.5
December	48.2	6	161.0	61.3
1936				
January	47.9	5	131.6	66.6
February	47.9	3	65.3	59.3
March	52.7	12	91.0	97.7
April	56.8	10	67.2	91.6
May	61.5	2	42.0	75.0

Table 3.—Development of progeny of California red scales on lemon fruits in a grove in Corona, Calif., 1935–36.

Group	Mother Scales	Average Period First Crawler to Final Count	Average Period First Crawler to First Mature Female	Date Last Females Matured	Live Mature Female Progeny per Scale		Average Live Immature Progeny per Scale		Progeny Mature and Alive When Removed	Average Empty Male Covers per Scale
					Maximum	Average	Unfertilized Females	Sex Unknown		
	Number	*Days*	*Days*		*Number*	*Number*	*Number*	*Number*	*Per Cent*	*Number*
1	32	88	49.9	Oct. 25	85	35.2	9.3	14.2	22.6	41.7
2	43	119	40.4	Mar. 27[1]	78	36.7	13.9	20.0	20.7	35.4
3	40	214	109.7	June 12	46	13.0	7.5	7.0	11.1	12.2
4	19	130	145.0[2] / 81.7[3]	July 17 / July 17	48	15.4	10.3	14.8	12.4	9.1

[1] No scales matured between Jan. 24 and March 20.
[2] Progeny of 7 mother scales that began reproduction from November to February.
[3] Progeny of 12 mother scales that began reproduction from March to May.

The fact that many immature progeny in the second group were alive in the spring of 1936 when the production counts were continued that long indicated that scales in all stages of development survived the low winter temperatures. When production began in October, as in the third group, the female progeny did not mature before March. During the winter months the number that developed to the mature stage greatly decreased, and from January 31 to March 7 only two progeny reached the mature stage, indicating a relatively dormant period in fertilization and growth.

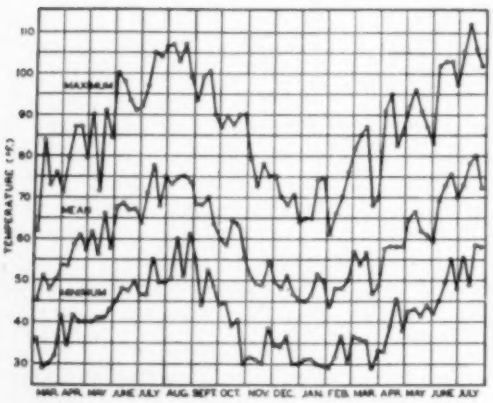

FIG. 1.—Maximum, mean, and minimum weekly temperatures in a lemon grove near Corona, Calif., from March 1935 to July 1936, inclusive.

The period between successive generations, as determined from the time the reproducing scales became mature until their first female progeny reached maturity, was found to be as short as 49 days. Such short records were infrequent and occurred during July and August, but records of 56 days for this period were common during the summer.

The reproductive period of many of the scales continued over a long period of time and resulted in a decided overlapping of generations. According to the records obtained it appears possible for some of the scales in as many as three generations to reproduce simultaneously.

CLIMATIC CONDITIONS.—The mean, minimum, and maximum weekly temperatures during the period of this study are plotted in figure 1. In general, the temperature and humidity during this period were normal for the locality. The winter probably was a little colder and the low temperatures were sustained a little longer than usual, but there were no especially low temperatures. On October 31 the temperature dropped to 30° F., probably killing many of the reproducing scales, for on November 1 and 8 approximately 28 per cent were dead. A minimum temperature of 29° F. was recorded on February 4, 6, and 7, and March 26, but there was no excessive mortality following any of these drops in temperature. The sudden low temperature of 30° F. on October 31 was more critical for the reproducing scales than 29° on subsequent dates.

DISCUSSION.—This study indicates that the red scale population may increase very rapidly, especially from June to the end of September. The increase is not evident until the female progeny become full-grown, for the minute live young may be overlooked in field inspections in the early summer, and the oversight may result in an incorrect estimate of the scale infestation in the grove during this time. A series of measurements showed that the average

area of scales in the early gray adult stage (before any increase in size after the second molt) was 0.71 sq. mm., and that of the full-sized insects in the late gray adult stage was 3.17 sq. mm. Thus, the area increased about 4.5 times during this period, which lasts only about 7 days in the summer. These facts assist in explaining the apparent phenomenal increase in the scale population that occurs under conditions suitable for rapid growth. On the fruit and trees in the field and on fruit removed to the packing house the scale population may be classified as light, although many immature scales are present. The subsequent rapid change in size of the scales previously present leads to a reclassification of the infestation in a short time.

LABORATORY STUDIES.—An experiment was also conducted in the laboratory to observe the reproducing insects more closely and obtain additional information on their potential productive capacity. Records were obtained of the total number of crawlers produced, the length of the reproductive period, and the daily rate of production.

Scales were reared on lemon fruits at an approximately constant temperature of 77° F. Individual cages made of large gelatin capsules, similar to those described by Bliss, Broadbent, and Watson (1931), were used. The end of the longer section of the capsule was cut off and placed over the insect before production began. The capsule was sealed to the fruit with a paste composed of powdered resin and ethyl alcohol, with a little glycerol added to prevent it from becoming too brittle. The top of the capsule was removed for observation, for the crawlers could not escape. The crawlers were removed daily with a camel's-hair brush and the numbers tabulated. The observations were made with the aid of a binocular microscope.

The productivity of a scale was based on the total number of dead and living crawlers found in the cages. The reproductive period included the time between the dates the first and last crawlers were produced.

Productivity records were obtained for 56 insects. The average number of crawlers produced was 263.2 per mother scale. The most prolific scale produced 576 crawlers in 138 days. The reproductive period averaged 51.4 days, and the longest period was 143 days, during which time 466 crawlers were produced. In both maximum records the decaying condition of the fruit near the end of the period was responsible for discontinuance of the records.

These data substantiate the high production records obtained in the field and indicate that when conditions are favorable even greater production may be expected in the field than was recorded in table 1.

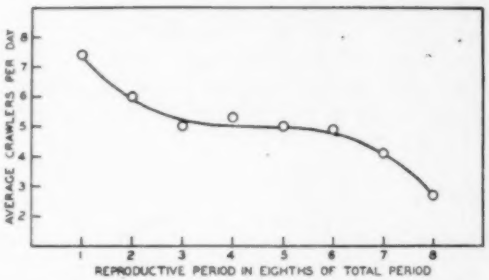

FIG. 2.—Average daily production of crawlers per mother scale in the laboratory at a constant temperature of 77° F.

Crawlers were usually produced each day, but occasionally several days passed without any reproduction, especially toward the end of the period. One mother scale produced on an average 5.1 crawlers per day, and as many as 15 crawlers were produced in a day by one scale. Reproduction began early in the morning, and by 9 o'clock from 75 to 80 per cent of the crawlers for the day were produced. The mother scales lived on an average 3.2 days after producing the last crawler, but one mother scale lived 15 days.

In general, the number of crawlers produced each day was relatively high at the beginning of the reproductive period. Following the high initial production daily production was fairly constant throughout most of the period and then dropped rapidly near the end. The average daily production per scale over the entire reproductive period is shown graphically in figure 2.

SUMMARY.—Field studies of the productivity of the California red scale, *Aonidiella aurantii* (Mask.), were started in a lemon grove in the vicinity of Corona, Calif., in the spring of 1935 and continued

until the summer of 1936. Productivity records were obtained for 194 scales on lemon fruits and were based on the number of progeny that settled.

The study included four groups of scales that began to reproduce at different times during the year. The average length of the reproductive period ranged from 64.5 days for those scales that began reproduction in the spring and early summer to 154.3 days for those that began reproduction in the late summer and fall. The minimum reproductive period was 7 days and the maximum was 287 days. The average number of progeny that settled per scale ranged from 65.6 for those scales that began reproduction in the winter to 158.5 for those that began in midsummer. The maximum number of progeny counted from one mother scale was 300.

Scales began reproducing in each month throughout the year. Many of those that began reproduction late in the summer lived until the spring of the following year, giving birth to crawlers in two seasons.

During the summer an average of 35.2 female progeny per reproducing scale developed to the mature stage. The maximum number from one mother scale recorded as reaching that stage was 85.

The productivity records of 56 scales reared in the laboratory at a constant temperature of 77° F. substantiated the high production records in the field.—6-23-43.

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The Influence of Repeated Fumigation with HCN on the Susceptibility of the California Red Scale

HAROLD R. YUST, HOWARD D. NELSON, and R. L. BUSBEY, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Previous studies of the California red scale, *Aonidiella aurantii* (Mask.), have shown that it is more resistant to fumigation with hydrocyanic acid in some localities than in others. Dickson (1941) and Yust *et al.* have shown that resistance is an inherited character. In a further study of resistance, reported in the present paper, the influence of repeated fumigations on the susceptibility of red scale populations to hydrocyanic acid was observed in the laboratory at Whittier, Calif.

METHODS.—Most of the experiments included strains that had been maintained in isolated adjacent compartments of the station insectary since 1935 (Yust & Busbey 1942). The nonresistant scales were obtained from Escondido, Calif., and the resistant scales from Corona. One of these strains is referred to as the laboratory-nonresistant strain and the other as the laboratory-resistant. In the summer of 1939 the laboratory-resistant strain was divided into two groups, one being propagated without fumigation; the other group usually being fumigated in each generation while in the second molt, before fertilization had occurred, with gas concentrations giving from 50 to 75 per cent mortality. Usually two groups of lemons were infested with scales of each group in each generation, one for propagation and the other for test purposes. By this procedure it was possible to determine the relative susceptibility of scales with and without a history of repeated fumigation.

The different stocks, on lemon fruits, were maintained under outdoor temperatures, but scales for the comparative tests were usually reared and treated at a constant temperature of 77° F. The procedure and the laboratory apparatus used in the fumigations were similar to those described by Yust *et al.* (1942). The scale populations that had been exposed to repeated fumigations are designated as "survivors." Some of the comparative tests were carried on with scales in the second molt, others with mature females. Each mortality figure was based on counts of 50 scales on each of 24 fruits.

Table 1.—Influence of repeated fumigation on the susceptibility of laboratory-resistant California red scales to fumigation with hydrocyanic acid.

Generation	Fumigations of Resistant Survivors	Tests with Scales in Second Molt			Tests with Mature Females		
		Concentration (Mg. per Liter)	Mortality		Concentration (Mg. per Liter)	Mortality	
			Laboratory-resistant	Resistant Survivors		Laboratory-resistant	Resistant Survivors
	Number		*Per Cent*	*Per Cent*		*Per Cent*	*Per Cent*
1	1	0.58	50.6	43.1	0.49	73.6	71.6
3	2	.59	23.8	17.4	.46	66.3	51.1
4	3	.58	42.8	32.6	.47	55.2	46.8
5	4	.59	33.6	22.2	.49	65.3	59.8
13	7	1.00	32.9	14.8	—	—	—
	12			6.8			
14	7	1.48	95.9	90.8	—	—	—
	13			59.4			
15	7	1.40	97.5	89.2	.52	83.7	77.8
	14			49.2			69.0

The laboratory-resistant stock was given 7 fumigations in 8 generations, and then the survivor group was subdidivided into 2 groups, 1 of which was continued without additional fumigations whereas the other was fumigated once in each of 7 generations until this stock had been given 14 fumigations. At intervals infestations were made at the same time with the laboratory-nonresistant, the laboratory-resistant, and the survivor scales. Later these scales were fumigated simultaneously with the same concentration of hydrocyanic acid. No tests were made between the fifth and thirteenth generations, and in the thirteenth and fourteenth generations the scales were reared at fluctuating temperatures.

RESULTS OF TESTS WITH LABORATORY STOCKS.—All fumigations killed from 98 to 99.9 per cent of the laboratory-nonresistant stock, although in the fourteenth and fifteenth generations no nonresistant scales in the second molt were fumigated. The results of the experiments with the different resistant stocks are given in table 1.

After two fumigations the resistant survivors were appreciably more difficult to kill than the laboratory-resistant strain. In the fourteenth and fifteenth generations the survivors of 13 or 14 fumigations were significantly more resistant to the gas than were the survivors of 7 fumigations, and the latter were significantly more resistant than the laboratory-resistant strain.

TESTS WITH VERY RESISTANT SCALES.—In another series of experiments, scales from the Kenner grove in San Fernando and the Andrews grove in Corona, both of which proved to be very resistant when they were brought to the laboratory in February 1941, were given seven repeated fumigations in eight generations. The susceptibility of these scales was compared with that of scales propagated without fumigation in treatments in four generations, as shown in table 2. The first test fumigation was done with mature females, the remainder with scales in the second molt. The scales in the last treatment had been reared at fluctuating temperatures.

Two fumigations had little effect on the resistance of these scales, but six treatments definitely increased their resistance.

TESTS WITH NONRESISTANT SCALES.—In the fall of 1940 scales were again obtained in Escondido from the grove in which the laboratory-nonresistant scales were originally obtained and were placed in a muslin-covered frame house located near the grove, where they were reared

Table 2.—Influence of repeated fumigations with hydrocyanic acid on the mortality of very resistant California red scales from the Kenner grove in San Fernando, Calif., and the Andrews grove in Corona, Calif.

Fumigations Given Progenitors of Survivor Stocks	Mortality			
	Kenner Stock	Kenner Resistant Survivors	Andrews Stock	Andrews Resistant Survivors
Number	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
1	75.7	73.4	72.0	69.3
2	94.2	92.6	95.4	93.0
6	93.3	85.2	91.0	77.9
7	75.1	41.8	73.2	42.2

for 2 years. The scales were kept at Escondido as an added precaution against contamination with insects from other localities. The scales were divided into two groups and placed in isolation cages. One group was treated in a portable fumigation chamber at Escondido in six successive generations and propagated from the survivors. The other group was propagated without intervening fumigations. After infestations had been made for propagating both groups, the reproducing scales were usually taken to the Whittier laboratory, where infestations were made simultaneously with these two groups and with laboratory-resistant and non-resistant scales. All four groups were treated in five generations, all in the second molt. The scales in the tests after the fourth and fifth fumigations had been reared at fluctuating temperatures. The results are given in table 3.

Table 3.—Influence of fumigations of the California red scale in the second molt in six successive generations on the susceptibility of relatively nonresistant scales from Escondido, Calif.

Fumigations Given Progenitors of Survivor Stock	Mortality			
	Laboratory Stock		Escondido Stock	
	Non-resistant	Resistant	Untreated	Survivors
Number	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
1	99.3	29.6	85.2	68.3
2	99.5	47.0	93.0	63.7
4	99.3	32.9	88.0	24.5
5	100.0	84.7	98.2	66.3
6	99.8	49.8	97.5	21.9

After the fourth fumigation the Escondido scales were more resistant than the regular laboratory-resistant strain. The untreated Escondido scales were more resistant than those of the laboratory-nonresistant strain, which was originally obtained from this same grove.

DISCUSSION.—When this study was started in 1939, it was assumed that the laboratory-resistant strain contained some nonresistant scales because other scale stocks were found that seemed to be more resistant. It was thought that a few fumigations would eliminate the nonresistant individuals and that the population would then become practically pure resistant. After the laboratory-resistant strain was given seven fumigations, the scale populations were as resistant as any known at that time, but additional fumigations increased still further their level of resistance. Especially resistant stocks of scales from groves in San Fernando and Corona, Calif., also became more resistant as the result of repeated fumigations in the laboratory. In view of the high mortality of the nonresistant strain in these tests, it is difficult to attribute increased resistance entirely to the elimination of nonresistant individuals in the original stocks. Further divisions and fumigations are planned, to see whether resistance will continue to increase, and whether the resistance which has been built up will be lost when treatments are discontinued.

It should not be concluded that the resistance of the field populations increases as rapidly as in the laboratory tests, because the conditions in the laboratory and in the field are not entirely comparable. In the laboratory the gas was uniformly distributed, so that each scale was equally exposed to it, and the fumigations were usually made on each generation before the females were fertilized. These females could then mate only with males that had survived a treatment. In the field the gas concentrations varied considerably, fumigations were less frequent, and mature females, which may have been fertilized by nonresistant males prior to treatment, survived.—6-23-43.

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Influence of Decreasing, Constant, and Increasing Concentrations on Results of Fumigation of the California Red Scale with HCN

HAROLD R. YUST, R. L. BUSBEY, and HOWARD D. NELSON, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In commercial field fumigation of the California red scale, *Aonidiella aurantii* (Mask.), with hydrocyanic acid, the concentration of the gas attains its maximum shortly after the cyanide is injected under the tent and then decreases to a low point by the end of the exposure period. This change in concentration per unit of time may be expressed by a curve which is frequently referred to as a decreasing-type concentration-time curve. If more nearly gastight tents were used in the field, the gas concentration would remain more nearly constant. The question often arises as to whether a decreasing-type concentration has any advantage over other types with the same average concentration. Gray & Kirkpatrick (1929) and Pratt *et al.* (1931) reported that high initial concentrations were essential to obtain satisfactory kills in the field. Moore (1933) concluded that "the type of concentration curve has no decided influence upon the kill providing there is a good distribution of gas." Lindgren (1941) showed that a high-peak type of concentration, such as is obtained in the field, offers a slight advantage over a low uniform concentration. In this study decreasing, constant, and increasing concentrations are compared as to their effectiveness in experiments with and without prefumigation exposures that produce protective stupefaction.

The fumigation tests were made in the laboratory under controlled conditions. The methods and apparatus used were the same as those described by Yust *et al.* (1942). The alteration of the apparatus for producing different concentrations with the same average (concentration $\times$time integral) is described by Fulton & Busbey (1943). Decreasing prefumigation concentrations that are likely to be encountered as drift-gas concentrations in the field were used and were in the range which had previously been found to produce marked protective stupefaction. The prefumigation exposure immediately preceded the final fumigation. Unless otherwise stated, both exposures were for 45 minutes at 59° F. and the scales were preconditioned and postconditioned for 4 hours at 59° F. Resistant scales on lemon fruits were used. The insects were either reared in the laboratory or obtained in the field. Fifty female scales in the same developmental stage were marked on each fruit prior to treatment, and each mortality record was based on 1200 insects. The mortality of untreated scales and of scales receiving only the prefumigation treatment was negligible.

CONSTANT VS. DECREASING CONCENTRATIONS, WITHOUT PREFUMIGATION.—Eight groups of scales in the second molt that had been reared at a constant temperature of 77° F. and a relative humidity of 65 per cent were fumigated for 40 minutes at the same temperature and relative humidity. The experiment was duplicated on another day and the results of the two tests were combined. For four groups the concentration of the gas was held constant at 0.88, 1.15, 1.49, and 1.78 mg. per liter, respectively. For the other four groups decreasing concentrations with averages of 0.88, 1.15, 1.37, and 1.66 mg. per liter, respectively, were used. None of the groups of scales in this experiment had been prefumigated. In figure 1 the mortality in probits is plotted against

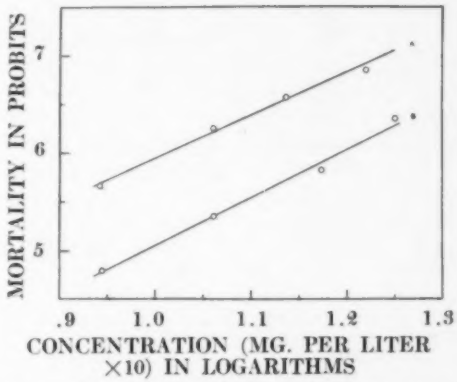

FIG. 1.—Mortality, in probits, of the California red scale fumigated in the second molt at different dosages with (*A*) decreasing, and (*B*) constant concentrations of hydrocyanic acid.

the concentration (mg. per liter×10) in logarithms as described by Bliss (1935).

A much better kill was obtained with decreasing concentrations than with constant concentrations. The regression equation for the data of the series of decreasing concentrations was $Y=6.16+4.43\ (X-1.047)$ and for the series of constant concentrations was $Y=5.45+4.89\ (X-1.082)$. The standard errors of the average probit and regression coefficient from the first equation were 0.02 and 0.26, respectively, and from the second equation they were 0.02 and 0.18, respectively. There was no significant difference in the slope of the lines but a highly significant difference in position. The median lethal concentration of hydrocyanic acid for the series of decreasing concentrations was 0.61 mg. per liter and for the series of constant concentrations it was 0.98 mg.

CONSTANT VS. DECREASING CONCENTRATIONS, WITH PREFUMIGATION.—Fumigations were also made with four constant and four decreasing concentrations on scales that had just been prefumigated, to determine the mortality when there was protective stupefaction. Mature female scales from the field were used and were prefumigated with concentrations ranging from 0.08 mg. per liter at the beginning to 0.02 mg. at the end. The final concentrations and the results are presented in table 1.

Table 1.—Mortality of mature female California red scales subjected, immediately after prefumigation, to fumigation with hydrocyanic acid at constant and decreasing concentrations.

Concentration, Mg. Hydrocyanic Acid per Liter			Mortality, Per Cent	
Constant	Decreasing			
Average	Range	Average	Constant	Decreasing
0.74	2.29–0.12	0.74	64.5±1.7	61.3±1.9
1.08	3.32– .17	1.08	73.2±1.9	75.7±1.9
1.43	4.36– .22	1.44	85.8±1.4	85.2±1.2
1.82	5.64– .26	1.83	94.2±0.9	93.6±0.8

When, as in this experiment, there was a prefumigation immediately before the final fumigation, the mortality of mature female scales was approximately the same for constant and for decreasing concentrations. Since without protective stupefaction of the scales as produced by prefumigation, decreasing concentrations gave better kills than constant concentrations, these results further show that with stupefaction there is more reduction in kill with decreasing concentrations than with constant concentrations.

To show the marked reduction in kill due to stupefaction when decreasing concentrations are used, mature female scales from the field were fumigated at four different decreasing concentrations, with and without a prefumigation that produced protective stupefaction. The four average concentrations in the tests that included prefumigation (during which the concentration ranged from 0.08 mg. per liter at the beginning to 0.02 mg. at the end) were 0.64, 1.06, 1.50, and 2.05 mg. per liter, and in the tests that did not include prefumigation the four averages were 0.20, 0.36, 0.52, and 0.64 mg. per liter. The concentration-mortality curves for the two series (with and without prefumigation) are plotted in figure 2.

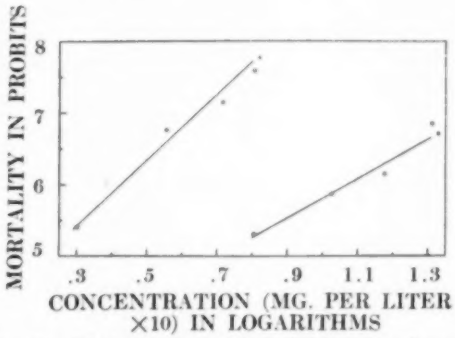

FIG. 2.—Mortality, in probits, of the mature female California red scale fumigated with different decreasing concentrations of hydrocyanic acid (*A*) without and (*B*) with prefumigation immediately prior to final fumigation.

The regression equation for the series in which the scales were treated without first being prefumigated was $Y=6.00+4.58\ (X-0.426)$ and for the series in which the scales were first prefumigated it was $Y=5.83+2.74\ (X-1.008)$. The standard errors of the average probit and regression coefficient from the first equation were 0.07 and 0.45, respectively, and from the second equation they were 0.06 and 0.36, respectively. The median lethal concentration for scales that had not been prefumigated was 0.16 mg. per liter and for those that had been prefumigated it was 0.51 mg.

It is usually assumed that increasing the concentration overcomes protective stupefaction. In this experiment such an effect would result in the mortality curves for prefumigation and no prefumigation being

closer together at their high concentrations than at their low concentrations, but so far as there was any difference in the slope of the two curves it was in the reverse condition. In another experiment with scales in the second molt the concentration-mortality curves were approximately parallel, so it is very improbable that increasing the concentration after prefumigation that has produced protective stupefaction increases the kill proportionately more than when there has been no prefumigation to cause stupefaction.

DECREASING, INCREASING, AND CONSTANT CONCENTRATIONS.—In further treatment, both with and without prefumigation, scales in the second molt and in the mature female stage were fumigated with three concentrations of the decreasing type, two of the increasing type, and a constant concentration, in all of which the average concentrations within each group were about the same. Treatments with the six different concentrations were made, on one day on scales that had not been prefumigated, and, on another day, on scales in the same stage that had been prefumigated. The scales were reared in the laboratory at fluctuating temperatures ranging from 68° to 92° F. and were fumigated at 59° F. Those in the second molt were prefumigated with concentrations ranging from 0.17 mg. per liter at the beginning to 0.04 mg. at the end, and mature female scales with concentrations ranging from 0.08 mg. to 0.02 mg. The final concentrations and the mortalities are given in table 2.

In the two groups in which prefumigation was not a factor the decreasing concentrations gave better kills than the constant concentration and the latter gave better kills than the increasing concentrations. This was previously shown at the Whittier laboratory.[1] With prefumigation, however, the difference in the effectiveness of the several types of concentration was practically eliminated. These data show that the toxicity of hydrocyanic acid gas to the California red scale is not proportional to the products of concentration and time under all conditions.

Table 2.—The influence of fumigations having different concentration-time curves on the kill of California red scales in the second molt and mature female stages when prefumigated and when not prefumigated.

TYPE OF CONCENTRATION IN RELATION TO TIME	FINAL FUMIGATION, MG. HCN PER LITER				MORTALITY, PER CENT	
	Not Prefumigated		Prefumigated			
	Range	Average	Range	Average	Not Prefumigated	Prefumigated
			Scales in second molt			
Decreasing	2.40–0.07	0.60	3.4 –0.11	1.00	9.73	63.6
Decreasing	1.81– .10	.61	2.62– .24	0.99	96.1	60.5
Decreasing	1.20– .25	.59	1.80– .48	1.01	91.9	57.5
Constant	0.60– .58	.59	1.00– .98	0.99	81.0	59.3
Increasing	.25–1.22	.60	0.59–1.78	.99	71.1	54.9
Increasing	.16–1.53	.62	.23–2.61	1.01	67.5	55.8
			Mature females			
Decreasing	1.20– .02	0.29	3.41–0.12	1.01	89.1	48.9
Decreasing	.92– .03	.30	2.54– .24	1.00	86.5	58.8
Decreasing	.59– .12	.29	1.80– .53	1.02	80.4	60.6
Constant	.31– .29	.30	1.00– .97	0.99	62.7	52.7
Increasing	.11– .63	.31	0.58–1.78	1.01	38.6	58.5
Increasing	.05– .90	.30	.23–2.59	0.99	23.3	62.6

In another experiment mature female scales obtained in the field were prefumigated with a concentration ranging from 0.09 mg. per liter at the beginning to 0.02 mg. at the end. Immediately thereafter they were fumigated with one constant concentration and three increasing concentrations, all giving approximately the same average concentration. The concentrations in the final fumigations and the mortalities are presented in table 3.

Again with prefumigation the kills were

[1] Unpublished manuscript by F. H. Lathrop, H. L. Cupples, H. R. Yust, and J. Hiley.

Table 3.—Mortality of stupefied mature female scales from fumigation with hydrocyanic acid at constant and increasing concentrations giving approximately the same average concentration.

Type of Concentration in Relation to Time	Concentration of HCN, Mg. per Liter		Mortality, Per Cent
	Range	Average	
Constant	1.23–1.20	1.22	77.2±2.4
Increasing	0.46–2.40	1.22	83.0±2.1
Increasing	.20–3.66	1.22	81.2±1.6
Increasing	.11–4.83	1.23	81.2±2.1

not significantly different with constant and increasing concentrations.

These results suggest that high initial concentrations are unnecessary in the field if high average concentrations are maintained, since after the first series of trees is fumigated the scales are almost always subjected to stupefying dosages of gas escaping through the tents. Therefore, the more uniform concentrations which would be maintained under more nearly gastight tents should be just as effective as concentrations with the same average and a high peak obtained with the present fabrics. Although it is true that without protective stupefaction the best kills were obtained with decreasing concentrations, it should be remembered that constant concentrations necessary to give satisfactory kills with protective stupefaction will give even better kills without it.

SUMMARY.—Resistant California red scales were fumigated in the laboratory with hydrocyanic acid to compare the effectiveness of decreasing, constant, and increasing concentrations, with and without prefumigation exposures that produced protective stupefaction.

Without protective stupefaction a better kill was obtained with decreasing then with constant concentrations, and a better kill was obtained with constant than with increasing concentrations. With prefumigation the differences in the effectiveness of the several types of concentration were practically eliminated.

The results suggest that high average concentrations are essential in the field and that high initial concentrations are unnecessary.

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DR. SANDERSON RETIRES

Dr. Dwight Sanderson of Cornell University, better known to entomologists as E. Dwight Sanderson, has retired from his active duties at Cornell University where he has spent more than 25 years in the field of Rural Organization and Sociology.

Previous to that time Dr. Sanderson had been in administrative work in experiment stations and earlier than that he was an active entomologist. He served as president of the American Association of Economic Entomologists in 1910.

Dr. Sanderson's winter address will be Ft. Lauderdale, Florida, 1009 E. 7th St.

The Effect of Proximity to Apple on the Extent of Oriental Fruit Moth Injury in Peach Orchards

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In connection with the experimental mass liberation of parasites of the oriental fruit moth, *Grapholitha molesta* (Busck), data have been gathered by the Moorestown, N. J., laboratory from 1937 to 1941, inclusive, concerning the injury to peach fruit caused by that insect in a considerable number of peach orchards of New Jersey and several other eastern States. Several instances have been noted in which peach orchards located adjacent to bearing apple trees have had a considerably greater amount of injury by the oriental fruit moth to the crop at picking time, through two or more successive seasons, than the average injury in peach orchards located at some distance from bearing apples. This discovery has stimulated an examination of all available data on the effect of the location of peach plantings with respect to bearing apple trees on the amount of injury caused to the peach crop by the oriental fruit moth.

Plantings of peach and apple, in combination, provide an environment that is especially favorable to development of the fruit moth throughout an entire growing season. In the spring and early summer the succulent twigs of peach are the most favored food of the oriental fruit moth, and at that time apple orchards are only sparsely infested. In midsummer, as the peach twigs harden, nearly all the fruit moth population is found in ripening peaches, if any are present. After harvesttime, peach orchards, in which there are few succulent twigs and no fruit, become unsuitable for increase of the fruit moth, but apple orchards in which there are early ripening varieties offer an abundance of suitable food. Larvae developing on apple at this time are, for the most part, overwintering larvae which will hibernate in the apple orchard. Many of the moths that will emerge from them in the spring will return to peach, when that host plant is once more a favored food.

Stearns (1928) included among his suggestions for reducing oriental fruit moth infestation the recommendation that in making new plantings it would seem advisable to restrict the interplanting of peaches and apples. Cagle (1930) and Schoene *et al.* (1937), as the result of careful studies of the number of moths trapped in peach and apple trees in several orchards in Virginia, have contributed much information on the relative prevalence of oriental fruit moths in peach trees somewhat removed from those of apple, in peach and apple trees interplanted or adjoining, and in apple trees at some distance from those of peach. By means of bait traps supplemented by other observations they were able to show that in locations where apples and peaches were interplanted or adjoining, oriental fruit moths were usually more numerous in peach than in apple trees in midsummer, but that this condition might be reversed in the fall months, and that larger numbers of oriental fruit moths might be found in apples than in peaches at the time adults emerge from the overwintering brood. These workers also noted the probability that such moths do not reproduce effectively in apple trees during the early season but may migrate to nearby peach trees. More moths were trapped in locations where peaches and apples were interplanted or adjoining than in peach trees at some distance from apple trees, or than in apple trees at some distance from peach trees. No data are presented to show whether oriental fruit moth injury to ripe peach fruit was greater in the peach orchards exposed to bearing apple trees than in orchards located at some distance from bearing apple trees.

Driggers (1940) reported on a survey of oriental fruit moth injury in 1939 in 22 orchards in New Jersey. He found that in orchards interplanted with apples or with other varieties of peaches ripening earlier than Elberta there was a greater degree of injury than in orchards not interplanted with apples or with peaches maturing before Elberta. The data on orchards interplanted with apples, however, were not, segregated from those of orchards interplanted with early ripening varieties of peaches.

Information acquired, during the 5-year period, concerning the effect of the proximity of bearing apple trees on the amount of injury caused to peach fruit by

Table 1.—Oriental fruit moth injury to peach fruit in orchards adjoining apples and those not adjoining apples in 10 districts.

District	Adjoining Apples		Not Adjoining Apples	
	Number of Surveys	Average Injury Per Cent	Number of Surveys	Average Injury Per Cent
Crozet-Afton, Va.	3	4.3	2	1.5
Staunton, Va.	3	13.7	2	28.0
Harrisonburg, Va.	3	32.0	2	46.5
Clearbrook, Va.	4	8.0	2	26.5
Martinsburg, W. Va.	2	8.5	3	4.0
Hancock, Md.	2	1.0	4	5.0
Smithburg-Ringgold, Md.	5	5.2	3	2.3
Mercer Co., N. J.	4	24.7	6	15.8
Burlington Co., N. J.	19	21.4	15	11.5
Gloucester Co., N. J.	5	9.4	7	9.4
Average (unweighted)		12.8		15.0

the oriental fruit moth is presented in this paper. In the following discussion the peach orchards under observation are considered to adjoin apples if one side or more of the peach orchard is contiguous to, or if the peach trees are interplanted with, apple trees that were of bearing age during the year prior to the observations. All orchards bore a crop during the year of the observations. During these 5 years 108 surveys of peach orchards have been made in which estimates of injury to fruit by the oriental fruit moth were obtained at the time of fruit picking, and in which information is available on whether the peach trees adjoined apple trees in the senses defined above. The varieties surveyed were Elberta or some variety ripening at about the same time as Elberta. The measurements of injury were obtained by collecting a random sample of 400 fruits from each orchard at picking time and dissecting the fruit for concealed injury.

Peaches adjoined apples in 61 of the surveys, and the average injury in this group was 16.2 per cent. In the remaining 47 surveys in which peaches did not adjoin apples, the average injury was 12.3 per cent. There was a difference of 3.9 ± 2.5 per cent in favor of lower injury in the orchards not adjoining apples, but this difference was not significant. Although this comparison has an advantage derived from the inclusion of a relatively large number of instances, it also has the disadvantage of the heterogeneous combination of orchard surveys from several districts during different seasons.

ORCHARD SURVEYS ARRANGED IN VARIOUS GROUPINGS.—In table 1, 96 of the orchard surveys are classified into 10 districts, in each of which it was possible to include two or more surveys of peaches adjoining apples, and two or more surveys of peaches not adjoining apples. Each group includes surveys made during one or more years from 1937 to 1941, inclusive. The last 4 districts listed in the table include orchards in which mass liberations of parasites were made during the season of the survey. The average observed injury for all districts was slightly greater in peaches not adjoining apples than in peaches adjoining apples. In 5 of the 10 districts the injury in peaches not adjoining apples was equal to or greater than the observed injury in peaches adjoining apples. In Burlington County, N. J., where the largest number of surveys have been made, there was a substantial difference—9.9 ± 4.3 per cent less injury in the orchards not adjoining apples. This, however, may have resulted from including in the group of orchards not adjoining apples a somewhat larger proportion of surveys from orchards receiving mass liberations of parasites than were included in the group adjoining apples.

In table 2 all the orchard surveys are classified by years. The differences between the yearly average percentage injury for the orchards adjoining apples and for those not adjoining apples have been calculated as follows: 1937, 12.4 ± 5.7; 1938, 1.8 ± 4.4; 1939, 7.9 ± 4.6; 1940, 9.6 ± 4.4; 1941, 8.1 ± 3.8. In the averages for 5 years, the orchards not adjoining apples had somewhat lower observed injury than the orchards adjoining apples, but the difference, 3.0 ± 3.5, is not significant. For the last 4 of the 5 years

Table 2.—Oriental fruit moth injury to peach fruit in orchards adjoining apples and in those not adjoining apples during 5 successive years.

Year	Adjoining Apples		Not Adjoining Apples	
	Number of Surveys	Average Injury Per Cent	Number of Surveys	Average Injury Per Cent
1937	5	8.4	5	20.8
1938	15	15.4	15	13.6
1939	25	16.0	12	8.1
1940	7	27.6	7	18.0
1941	9	13.7	8	5.6
Average		16.2		13.2

the average injury was greater in the orchards adjoining apples, but only in 1940 and in 1941 was the observed difference significant.

There is substantial evidence in table 1 that oriental fruit moth injury in Burlington County, N. J., was lower in orchards not adjoining apples. Since orchards in this same county comprise a majority of the observations included in table 2 for the years 1940 and 1941, which showed injury significantly lower in the orchards not adjoining apples, a more careful analysis of the data from that county is presented in table 3. In this table the orchards which received mass liberations of parasites have been separated from those that did not receive liberations. In both cases there was a lower average injury in the orchards not adjoining apples, but the differences are not significant.

Table 3.—Oriental fruit moth injury to peach fruit in orchards adjoining apples and in those not adjoining apples in Burlington County, N. J.

	Adjoining Apples		Not Adjoining Apples		
Orchards	Number of Surveys	Average Injury Per Cent	Number of Surveys	Average Injury Per Cent	Difference, Per Cent
Receiving parasite liberations	5	17.8	8	7.7	10.1±5.4
Not receiving parasite liberations	14	22.6	7	15.9	6.7±6.8

POPULATION ESTIMATES OF LARVAE.—If there is a tendency for peach orchards adjoining apples to have a larger infestation of the oriental fruit moth than orchards not adjoining apples, it should be possible to find evidence of it in population estimates of the larvae in the orchards during successive broods. Such estimates have been obtained for a number of orchards and are presented in table 4. Only those orchards are included in which no mass liberations of parasites were made during the same season as the estimate. The number of larvae per tree for first and second broods was determined by rearing all the oriental fruit moth worms from all infested twigs and immature fruit drops from sample trees uniformly distributed over the orchards surveyed. The estimate of the number of larvae per tree for the third brood was determined by dissection of fruit samples taken at picking time. Comparable data for orchards adjoining and orchards not adjoining apples are available for two years, 1938 and 1940. All the orchards in this survey were located in New Jersey.

Table 4.—Estimates of the number of oriental fruit moth larvae per tree for the first three broods in peach orchards adjoining and those not adjoining apple trees.

	Larvae in Peach Orchards (Average per Tree)					
	Adjoining Apples			Not Adjoining Apples		
Year	First Brood	Second Brood	Third Brood	First Brood	Second Brood	Third Brood
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
1938	11.4	18.1	153.5	1.2	24.3	67.7
	40.2	23.7	91.6	16.0	17.7	22.5
	13.1	4.0	8.3	11.1	8.9	39.7
	10.2	24.0	113.8	1.3	1.4	12.3
	8.4	16.0	94.9	13.8	10.0	18.5
Average	16.7	17.2	92.4	8.7	12.5	32.1
1940	12.9	24.8	169.5	10.1	9.3	233.7
	41.0	23.0	336.0	9.3	15.7	83.4
	44.6	55.2	262.7	18.0	25.1	90.5
				11.9	17.5	345.5
Average	32.8	34.3	256.1	12.3	16.9	188.3

These data indicate a consistently greater infestation by the larvae of each brood in the orchards adjoining apples. This tendency was particularly marked in the first brood during both years and in the third brood in 1938. The considerably increased numbers of first-brood larvae per tree in peaches adjoining apples may have been the direct result of migration of moths emerging from the overwintered brood in adjoining apple trees. The lack of any relative increase thereafter in peach trees adjoining apples may have been because the oriental fruit moth infestation in apples during early and midsummer is negligible. The ratios of increase from the first to the second brood, or from the second to the third brood, were not on the average greater in the orchards adjoining apples. Other interesting points shown in these data for three of the four series are the relatively small increase in the number of larvae per tree from first to second brood and the much greater increase from second to third brood.

SUMMARY AND CONCLUSIONS.—A study has been made of extensive data accumulated by the Moorestown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine on the density of oriental fruit moth populations in peach orchards and the amount of injury to ripe fruit, to determine whether peaches in orchards adjoining or interplanted with bearing apple trees are generally more severely injured by the oriental fruit moth

than in those not adjoining bearing apple trees. There is considerable evidence that moths which emerge from the overwintered brood produced in apples in late summer and fall may migrate from apple trees to adjoining peach orchards in sufficient numbers to increase the first-brood population in such orchards to a density above the average of first-brood oriental fruit moth population in peach orchards not adjacent to apple trees. There was also a tendency toward a somewhat greater proportion of fruit moth injury in peach orchards adjacent to or interplanted with apples than in those not adjacent or interplanted, but this tendency was highly variable, and from the available data it was not possible to demonstrate consistently significant differences.

Because of the tendency towards greater fruit moth infestation, the planting of peach orchards adjacent to apple should be avoided if sites equally satisfactory in other respects are available. On the other hand, the increases in oriental fruit moth injury to peaches resulting from proximity to bearing apples have not been generally large enough to warrant recommendations against the planting of peaches in such situations, if sites not exposed to the migration of fruit moths from apple are unavailable.—8-5-43.

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Tests of 4,6-Dinitro-o-Cresol Emulsion Against Overwintering Codling Moth Larvae

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In 1941 the writers obtained favorable results in killing overwintering larvae of the codling moth, *Carpocapsa pomonella* (L.), by spraying the trunks and scaffold limbs of apple trees with various materials (Yothers *et al.*, 1942). A kill of 95 per cent was obtained with 8 pounds of 4, 6-dinitro-o-cresol (also called 3, 5-dinitro-o-cresol but hereinafter called dinitro-o-cresol), 10 gallons of stove oil, 4 pounds of sodium lauryl sulfate, and a penetrant consisting of 1.5 gallons each of ethylene glycol monobutyl ether and trichloroethylene per 100 gallons of spray. The same spray mixture with only 4 pounds of the dinitro-o-cresol resulted in a 94 per cent kill.

Subsequent laboratory tests indicated that practically 100 per cent mortality could be obtained with a mixture containing only 2 pounds of dinitro-o-cresol per 100 gallons, 10 gallons of stove oil, and 3 pounds of sodium oleate, but without the penetrant used in the 1941 formula. In orchard tests in 1942, however, this spray killed only 62 per cent of the larvae in a block of 145 Winesap trees. Even though the kill was far from complete, there was evidence of some reduction in infestation, compared with untreated trees or those that were only scraped and banded, as indicated in table 1. The numbers of moths caught in bait pots, two of which were maintained in each block, are also shown in this table.

LARGE-SCALE ORCHARD TESTS IN 1943.—In the spring of 1943 large-scale orchard

Table 1.—Results of large-scale orcard tests of dinitro-o-cresol emulsion against hibernating codling moth larvae, Yakima, Wash., 1942.

TREATMENT[1]	WORMY FRUIT AT HARVEST, PER CENT	NUMBER OF MOTHS CAUGHT IN BAIT POTS
Dinitro-o-cresol spray	8	3,298
Scraped and banded	11	4,256
No treatment	18	5,235

[1] All blocks received a summer spray schedule of lead arsenate.

tests were made of the spray mixture used in 1941, containing 4 pounds of dinitro-o-cresol, and with a second mixture containing 3 pounds of dinitro-o-cresol, 15 gallons of stove oil, 6 ounces of sodium lauryl sulfate, and 3.78 grams of ferric chloride per 100 gallons of spray. The ferric chloride aided in breaking the emulsion so that the stove oil was free to act as a solvent for the wax in the cocoons. The mixture prepared according to the first formula cost 8 cents per gallon; that with the second formula, 4 cents.

These sprays were applied to large and average-sized Winesap and Jonathan trees in 3 orchards, each treatment including 122 to 140 trees. The sprays were prepared in the orchard by dissolving the dinitro compound in the oil by heating. While this was being done, the water and emulsifier were placed in the spray tank with the machine running. The solution of dinitro-o-cresol in oil was then added through the spray pump injector, followed by the penetrant or the ferric chloride. These sprays were applied March 25 to April 6. Bordeaux-type nozzles were used, each attached to a quarter-inch rod from 5 to 8 feet long. Each nozzle was adjusted to deliver approximately 1 gallon per minute at 150 pounds pressure. About 3 gallons of spray per tree was required in 2 orchards, and 5.4 gallons for the much larger trees in the third orchard. The first treatment was tested in all 3 orchards; the second treatment in only the third orchard. The trees in this orchard, in which both treatments were tested, were very large and old, with much rough bark higher up than could be reached with the spray rods. In addition, it was windy while most of the spraying was done in this orchard and difficult to drench the upper scaffold limbs thoroughly.

Between April 14 and 17, 9 trees per treatment in each orchard were examined, 728 to 1549 larvae being found in each lot of 9 trees.

With the first mixture the results were in excellent agreement with the 1941 results. The mortality in the first two orchards averaged 94 per cent. In the third orchard, where conditions were less favorable for effective spraying, the kill with this spray was only 86 per cent. With the second spray, containing ferric chloride, which was tested in the third orchard only, the kill was 80 per cent.

MISCELLANEOUS ORCHARD TESTS.—In another series of tests several mixtures containing dinitro-o-cresol and sodium lauryl sulfate, with and without the penetrant used in 1941, were applied to the trunk and roughbark limbs of three to five trees. Various pressures and two methods of application were used, the spray rod with bordeaux-type nozzle and a spray gun with a disk aperture of .048 inch. In most cases the spray mixture was prepared as in the previous experiments, but in one test the dinitro compound was dissolved in acetone[1] before being added to the penetrant and oil. This mixture was then emulsified by pumping it through the spray machine injector into the spray tank containing water and sodium lauryl sulfate. This method avoids heating the stove oil to effect complete solution of the dinitro-o-cresol, its solubility in stove oil being only 0.2 pound per gallon at 25° C. All but two of the mixtures contained the penetrant mentioned earlier in this paper, at the rate of 3 per cent by volume. The stove oil had the following specifications:

Distillation range, middle 80 per cent	194° to 269° C.
Unsulfonated residue (California method)	78 per cent
Viscosity, Saybolt, at 100° F.	32 seconds

The sprays were applied April 6 and 7, and examinations were made April 19 to 26. The results are summarized in table 2.

The mixtures prepared without the penetrant and the mixture containing only 2 pounds of dinitro-o-cresol per 100 gallons killed a smaller percentage of the worms than the mixtures containing the penetrant and 3 or 4 pounds of the dinitro compound. Otherwise, the differences were small, and probably not significant.

Codling moth cocoons are usually more readily wet by a spray that is directed up under the rough bark than by one directed from above, especially on scaffold limbs. Larvae not reached by the upward spray will be wet by the excess spray draining down the tree. In general, the larger the proportion of larvae on the trunk and lower scaffold limbs, in the crotches, and in the soil at the base of the tree, the greater will be the kill. Larvae under rough bark on the upper scaffold limbs are more difficult to reach with the spray.

Dinitro-o-cresol is toxic to trees in the

[1] Wain (1942) found that dinitro-o-cresol is very soluble in acetone (100.6 grams per 100 grams of solvent).

Table 2.—Results of miscellaneous orchard tests with dinitro-o-cresol emulsions against overwintering codling moth larvae, Yakima, Wash., 1943.

(Quantites for 100 gallons of spray mixture)						
Dinitro-o-Cresol, Pounds	Sodium Lauryl Sulfate, Pounds	Stove Oil, Gallons	Application Time per Tree, Minutes	Pressure, Pounds	Number of Larvae Examined	Mortality, Per Cent
			Applied with bordeaux nozzle			
3	¾	15[1]	3	150	255	83
3	¾	20[1]	3	150	176	86
2	4	10	3	150	127	88
3	4	15	3	150	164	99
4	4	10	6[2]	150	95	100
4	4	10	3	400	456	91
4[3]	4	10	3	150	163	95
			Applied with gun			
4	4	10	3	150	101	96
4	4	10	2	250	79	99
4	4	10	1½	400	58	97

[1] Penetrant omitted.
[2] Sprayed a second time.
[3] Dinitro-o-cresol dissolved in acetone before being added to penetrant and oil.

growing season, but no serious injury has been observed from emulsions as used in a delayed dormant spray. Some fruit buds are killed and leaf buds retarded on water sprouts and twigs in the lower center of the trees, especially if the material is applied after the period when the trees are strictly dormant. This injury is of little significance, however, since it merely eliminates a few apples that lack color and seldom become more than C grade or culls.

CONCLUSIONS.—Results of orchard tests with an emulsion containing 4, 6-dinitro-o-cresol, stove oil, and a suitable emulsifier and penetrant have proved its effectiveness as a dormant spray to kill overwintering codling moth larvae in their cocoons on apple trees. At a cost for materials of approximately 8 cents per gallon, or 16 to 40 cents per tree, about 95 per cent of the larvae can be destroyed. About 2 to 5 gallons of spray material are required for average-size bearing trees. The material is toxic to opening buds, and should be applied as a dormant spray to the trunk and scaffold limbs only.—7-6-43.

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VARIOUS QUARANTINES

The State Plant Board of Mississippi recently published notices of 1943 revisions of its sweet potato weevil quarantines relating to infestations in that and other States and of its European corn borer quarantine. Rule 31, relating to fumigation for the San Jose scale, now provides for the acceptance of the methyl bromide method, as well as the use of hydrocyanic acid gas. The Mississippi rule relating to citrus canker has been repealed.

Alabama's nursery regulations as revised September 24, 1943, provide for reciprocal agreements with other States in the use of the certificate tag of the destination State.

The Wyoming State nursery law as amended June 30, 1943, provides for reciprocal agreements with other States in the matter of the nursery fee, posting of bond, and shipping-tag requirements. A license is still required to do business in the State.

Iowa's quarantine relating to the European corn borer was revised August 9, 1943. The intrastate and interstate restrictions, it is said, now conform to the quarantines of other central States.

Reactions of the Codling Moth to Artificial Light and the Use of Light Traps in Its Control[1]

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Lead arsenate sprays are used almost universally for controlling the codling moth, *Carpocapsa pomonella* (L.), on apples. Their use has certain disadvantages, however, particularly the excessive residues on marketing fruit, and in recent years many experiments have been designed to find a substitute, either complete or partial.

Projects in supplementary control measures have been handicapped by the lack of detailed knowledge of the physiology and behavior of the insect, and studies leading to a better understanding of its peculiarities have sometimes been undertaken along with control projects. Since the codling moth has long been known to be both photopositive and chemopositive, these two tropisms have been studied with a view to their utilization in control.

In 1927 the senior author, under the direction of P. J. Parrott, of the New York State Agricultural Experiment Station, in association with Maurice W. Nixon, of the Empire State Gas and Electric Association, began a series of experiments designed to furnish information on the responses of the codling moth to light and the possibilities in the use of light traps for its control. These experiments were carried on continuously over a period of 14 years, ending, at least temporarily, in 1940. The active work of the last 4 years of the studies was done by the junior author. A report on these experiments, especially the results of the last 4 years, is in preparation. In the present paper the principal published information on the responses of the codling moth to light and the use of light traps in control experiments has been summarized briefly, together with some hitherto unpublished information from the writers' experiments. No attempt has been made to cover the early history of the subject, which consists mainly of incidental observations and opinions supported by very little evidence.

ATTRACTIVENESS OF DIFFERENT LIGHT SOURCES.—Several investigators have reported studies to determine the light sources and, specifically, the wave lengths of light most attractive to the codling moth.

In the first publication on the series of investigations conducted under his direction, Parrott (1927) reported that several species, including the codling moth, showed a distinct preference for the violet end of the spectrum. Corning glass filters were used to isolate the different regions of tungsten-filament lamps.

Peterson & Haeussler (1928), using standard tungsten-filament lamps with variably selective color filters approximately the same as those used by Parrott, found that the moths exhibited a distinct preference for blue and violet when given a choice of colors from red through violet. They used the following Corning glass filters: *Selenium Red, G24; Selenium Orange, G34; Noviol C, G38H; Grass Green, G401CZ; Dark Blue, G54; Violet, G53C; Blue Purple Ultra, G585M; Red Purple Ultra, G586A;* and *Daylite, G57.* Peterson & Haeussler stated that violet light was more attractive than blue. In their tests and in those of Parrott (1927) the wave-length ranges of the filters overlapped considerably. Equalization of intensities was accomplished by varying the distance between the light source and the filter. The experiments showed only that the blue through violets rays from a tungsten-filament light source were the most attractive components of that source.

Herms & Ellsworth (1934) reported that light blue was most attractive to the codling moth, and that in field tests worminess of fruit was reduced in trees equipped with blue-light traps but not in trees with white-light traps. Blue-light traps also attracted more females than males in these experiments. The blue-light source was a glass mercury-vapor tube.

Headlee (1932) studied the attractiveness of four kinds of artificial light to the

[1] This work was carried out under a cooperative arrangement with the New York Agricultural Experiment Station at Geneva and the New York State College of Agriculture at Cornell University.

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moths and the effect of each on other behavior characteristics. He described these lights as follows: *Mazda C*, heavy distribution in the red; *Mazda CX*, heavy distribution in the violet; mercury-vapor daylight, heavy delivery in the violet and ultraviolet; and red-painted *Mazda C*, heavy emission in the red. He found the mercury-vapor lamp to be the most attractive to the moths. He further noted that both the *Mazda C* and *Mazda CX* lamps reduced the infestation but permitted considerable oviposition; the mercury-vapor lamp stimulated normal activity, including oviposition; and the red-painted *Mazda C* stimulated abnormal activity, such as swarming around twigs in direct light.

Collins (1934) found that temporary morphological changes in the compound eyes of the codling moth, involving a shifting of the iris-pigment granules, took place under the impact of light, and that these changes were correlated with changes in the behavior of the moths. Collins & Machado (1935), accepting the fact that the codling moth is most stongly attracted by blue light, discovered that the mercury-vapor light also elicited a more rapid photochemical reaction in the eyes, as evidenced by the pigment migrations. The 75-watt tungsten-filament lamp had three times as great a visual intensity to the human eye as the mercury tube, and radiated 33 per cent more total relative energy; but in the region of 300 to 700 mμ, the region that presumably includes the bands to which the codling moth is most sensitive, the mercury tube transmitted more than 11 times as much energy as the tungsten lamp. They concluded that, of two light sources having approximately the same continuous spectrum, the more brilliant source elicits the more rapid photochemical changes in the eyes and is the more attractive to the moths; and that, of two light sources of unequal spectral range, the one including the bands which evoke the more rapid photochemical changes, even though its visual intensity and total relative energy are less, will prove the more attractive.

Collins & Machado (1935) also reported that sun lamps transmitting ultraviolet were equally as attractive when most of the far ultraviolet was screened out, and concluded that the near ultraviolet and violet and blue regions of such sources were the most attractive. Since sun lamps dissipate a large amount of energy in other regions, the specially designed mercury-vapor tubes seemed to be the most efficient light source, the greatest portion of their radiated energy lying in the desired regions.

Bourne (1936) tested blue, green, amber, red, and white lights, and found blue to be the most attractive.

Eyer (1937), in preliminary tests, found that the moths preferred blue or violet light. In the laboratory 100-watt *Mazda* lamps attracted more moths than light-blue mercury-vapor tubes, but in the field mercury-vapor tubes were more attractive. In the field tests a few moths were involved, sometimes less than a one-per-day average for 20 days, but the inferences drawn are in agreement with those of others—namely, that mercury tubes which produced 300 to 700 lumens within the range of 3000 to 7000 angstrom units (largely blue, violet, and ultraviolet) were most attractive.

Marshall & Hienton (1938) suggested three principal characteristics that influence the attractiveness of light to the codling moth—(1) intrinsic brilliance, (2) the size of the luminous area, and (3) the color. Several light sources were used in their experiments, listed as G-5, 250-watt CX, photoflood lamps, 100-watt *Mazda C*, *H-3* special, 100-watt robin's egg blue, dark-blue 200-watt *Mazda C*, and fluorescent tubes. Various filters were also used at different times to isolate spectral regions. When other conditions were equal, the dark-blue 200-watt tungsten-filament lamp showed the greatest attractiveness. The findings of Collins & Machado (1935) were substantiated, that in ultraviolet sources the blue and violet region alone is as attractive as one including near ultraviolet as well. The suggestion was advanced that far ultraviolet may add to the attractiveness of blue and violet.

Hamilton & Steiner (1939) tested the following light sources: Mercury-vapor tubes, G-1 mercury-vapor bulbs, 250-watt frosted CX, 300-watt clear *Mazda*, 200-watt clear *Mazda*, 150-watt clear *Mazda*, 60-watt frosted *CX*, 60-watt clear *Mazda*, and a 250-watt clear spotlight. They found the mercury-vapor tube and the G-1 mercury-vapor bulb to be about equal in attractiveness, and superior to *Mazda* lamps of 200 watts or less.

In general, these experiments on light sources gave consistent results, indicating that the codling moth is most strongly attracted by the blue and violet end of the visible spectrum. The mercury-vapor tube appears to be the most efficient lure where attractiveness alone is concerned, since it has a high output of blue and violet, and dissipates less of its energy in nonattractive regions. It will be noted later, however, that attractiveness alone is not the only factor to be considered in control experiments.

EFFECTS OF ILLUMINATION.—Several investigators have studied the effects of artificial light, other than as a trap lure, upon the activities of the moths. Parrott and Collins (unpublished data), early in their control experiments, noted that, while the mercury-vapor traps frequently attracted the largest numbers of moths, the injury to the fruit in trees containing them not only was reduced less than in the Mazda-lighted trees but in some instances was higher. Headlee (1932) noted that mercury-vapor tubes seemed to intensify the activity of the moths, for oviposition was heavier under the influence of the lights. Headlee, Herms (1929), and Herms & Ellsworth (1934) found that oviposition could be inhibited by floodlighting trees with *Mazda C* lamps.

TYPES OF LIGHT TRAPS.—Most of the recent control experiments have been made with a trap that electrocutes the moths on contact by means of electric grids surrounding the light source. Parrott (1927) began his experiments with a simple trap consisting of a light bulb suspended over a large, shallow pan of water. Collins & Nixon (1930) reported a certain amount of control of the bud moth and the fruit tree leaf roller with this trap. Later they used both this type and the electrocuting trap, and finally Parrott & Collins (1934, 1935) and Collins & Machado (1937) made tests with the electrocuting trap exclusively. The electrocuting trap appeared to attract and kill more moths wherever used, and was more easily handled in different positions in the tree. The best results were obtained when the trap was hung as high and as near the center of the tree as possible. In this position the water-pan trap not only was difficult to handle but also cast large shadows. The electrocuting traps were equipped with wire-mesh baskets, and therefore in the high, central positions could spread their light evenly through the trees.

Bourne found that he could increase the efficiency of the water-pan trap by adding a film of oil, and by raising the bulb so that the lower parts of the tree were not in the shadow of the pan. He found the electrocuting traps to be superior to the water-pan traps.

Herms & Ellsworth, Patterson (1937), Marshall & Hienton (1935), and Hamilton & Steiner used the electrocuting traps. Their investigations, as well as those of Parrott & Collins, and of Collins & Machado, were concerned chiefly either with the light source as such or with the control possibilities of a trap the efficiency of which had been demonstrated.

Worthley & Nicholas (1937) studied different types of traps with a view to finding one cheaper than the electrocuting types. They found that the most effective trap with light alone as a lure was the electrocuting type, but that a trap consisting of a light and reflector suspended above molasses-water bait in a 12-inch pan was even more effective. Worthley and Nicholas compared the catches in the following six types of traps: (1) a 75-watt *Mazda* lamp enclosed by an electrocuting grid; (2) a 75-watt *Mazda* lamp in an unpainted trapping globe; (3) the same as (2) with the globe painted black at top and bottom; (4) the same as (2) with the globe painted to give light only through slots; (5) reflector and baffles over a 12-inch pan, with bait and light; and (6) a 6-inch can with bait, no reflector, and no light. The trapping globe was a flattened cylinder of opal glass 8.5 inches in diameter, with three funnels molded into its circumference at equidistant points. Each funnel pointed toward the light source within, and was ground off at the apex to form an entrance slot 1.5 by 0.5 inch to admit insects attracted by the light. These globes caught the fewest moths when used unpainted, with light emanating from the entire surface, and the most moths when painted to show a band of light about the funnels. Of all traps used the type designated as (5), with both bait and light, captured the most moths.

In experiments conducted in 1936 Eyer (1937) compared the catches in traps containing four types of mercury-vapor lamps enclosed in two types of electrocuting

grids and one trap equipped with a suction-fan device. He had previously tried the simple water-pan trap with a lamp suspended over it. The electrocuting devices and the suction-fan trap caught more moths than the water-pan traps.

LIGHT TRAPS AND BAIT TRAPS.—Bait traps or chemical baits as a supplement to the light traps were used in many experiments. As has been mentioned, Worthley and Nicholas found that a trap consisting of a light and reflector suspended above molasses-water bait was more effective than any other. Eyer also found that combined bait and electrocuting light traps captured more moths than either lure used separately. Collins & Machado obtained similar results (unpublished data) and also found that the combined catches of light traps and bait traps operated independently in the same tree were larger than those of either trap alone. There was a general agreement that light traps alone captured more moths than bait traps alone. Bait traps captured a higher percentage of females, but the total catch of females generally was larger in the light traps. For example, Hamilton and Steiner recorded on an average 26.4 moths per trap in a 35-acre baited area and 126.9 moths per trap in a 5.25 acre light-trap area in 1934, a year of heavy infestation. The percentages of females were higher in the bait traps (66 per cent) than in the light traps (44 per cent), but the actual numbers of females were much higher in the light traps.

POSITION OF TRAPS.—There appears to be general agreement that the most effective position for a trap is in the region of the greatest normal activity of the moths. Eyer mounted traps on the cross arms of poles erected close to the trunks of the trees at a height sufficient to illuminate the upper third of the tree. Data presented by Hamilton and Steiner emphasized the importance of the position of traps. Traps 18 inches above the foliage captured on an average 46 moths each; those within 18 inches of the foliage, 66 moths; those with the basket lowered into the foliage, 81 moths; and those with the entire trap lowered into the foliage, 136 moths. The best location appeared to be as high in the tree as possible, with only a small amount of foliage near and above the top of the trap. Data obtained by Marshall & Hienton (1935) and by Collins & Machado (unpublished) pointed to the same conclusion. Patterson, however, found no correlation between codling moth catch and height of trap or proximity to foliage.

NUMBER OF TRAPS.—In early experiments Collins (unpublished reports) had one block of trees with one trap to every five trees and one block with one to every nine trees, as well as a block with a trap in every tree. The one-to-nine block was early abandoned as a control experiment. The traps in the one-to-nine and one-to-five blocks captured many more moths per trap than those in the one-to-one block, but the injury from the codling moth, bud moth, and fruit tree leaf roller was reduced only in the one-to-one area. Bourne stated that his electrocuting traps captured more moths in outside rows, and he recommended a trap in at least every second tree. Patterson had one trap in every fourth tree the first year, but in the following years he had a trap in every tree except three. Collins & Machado (1937), and Hamilton & Steiner concentrated their control studies on the trap-in-every-tree plan, which is probably the only arrangement that can be expected to cause appreciable reductions in infestation, at least with the light sources thus far used. Hamilton & Steiner found that none of the lamps used by them were powerful enough to attract moths more than 35 feet.

INFLUENCE OF TIME OF DAY, TEMPERATURE, AND HUMIDITY.—The activities of the codling moth are influenced strongly by temperature and humidity, and there is general agreement that during the time of day when moths are most active (twilight) these factors must be in a certain balance to give maximum activity. Headlee stated that moths began to fly under favorable temperatures promptly after the sunlight had fallen to 30 foot-candles, and that flight increased until the light dropped below 1 foot-candle, when it tapered off and stopped at complete darkness.

Collins (1934) found that moth activity was greatest when, in either morning or evening twilight, the midpoint in physiological and morphological photic adaptation occurred, which was at about 1.5 footcandles. In June, on clear days, this point was reached at about 7:45 P.M. and 4:30 A.M. In the evening moths were not attracted to lights until, on the periphery

of the tree, the illumination from the light traps exceeded the atmospheric illumination. Hamilton & Steiner gave an atmospheric illumination of 0.2 footcandle and 7:30 P.M. as the point after which moths generally began to be captured.

Collins & Nixon stated that when the temperature fell as low as 60° F. the flight was definitely inhibited, and Collins found this statement corroborated in all later work. Bourne found that rain reduced the catches, but that there was usually a heavy catch the night following a rainy one. He considered that temperature was the most important single factor governing catches at light traps. Eyer observed that bait pails were ineffective at temperatures below 60° and above 80°, but attributed these results partly to the effect of temperature on the bait. Patterson states that practically no moths were captured in light traps at temperatures below 60°.

SEX RATIOS.—Parrott & Collins (1934, 1935) and Collins and Machado (unpublished) found over a period of years that light-trap catches averaged between 40 and 45 per cent females, and those in bait traps between 65 and 70 per cent females. In 1933, in 13 trees that had both light traps and bait pails, the average number of females per light trap was 105, as compared with 57 per bait pail. The total catch of moths per trap was also much greater in the light traps. Virgin females and older females that had not oviposited were frequently caught, but no percentages were calculated.

Herms & Ellsworth reported catches of 43 and 45 per cent females in mercury-vapor traps and 25 per cent females from a small number of moths in a 60-watt (white) lamp trap. Worthley and Nicholas, for 1936, reported 28 to 45 per cent females in several types of light traps, 46 per cent in a combination light and bait trap, and 79 per cent (but fewer individuals) in a trap containing bait alone.

Hamilton & Steiner, for 1934, reported 44 per cent females in light traps, and 66 per cent females in bait traps. For another year, 1935, the averages were 35 and 55 per cent with a much smaller infestation. In 1936 their averages were 36 and 52 per cent. Each year the total actual catches were higher in the light traps.

Peterson & Haeussler, as well as Collins (unpublished), found no intrinsic difference in the response of the two sexes to lights in the laboratory.

CONTROL EXPERIMENTS.—Many experiments that have contributed valuable information relative to light-source preference, reactions to different wave lengths of light, relative efficiency of various types of traps, best position for traps, effects of light on oviposition, and other relations of the moth to light have been of little value from the standpoint of control. This has been either because the tests were not designed to furnish information on control, or because they were on too small a scale. Steiner (1940), with an extraordinarily large amount of data, has clearly shown the necessity for large blocks of trees in bait experiments, and he and others have shown that the same factors operate in light-trap tests.

In some experiments the lighted trees were treated with a calyx spray and one or more cover sprays during the growing season. Other experiments included untreated trees and lighted unsprayed trees, in addition to the lighted and unlighted sprayed trees. In many references the term "unsprayed" should be interpreted as referring to codling moth cover sprays only, since trees so described might have received the early spring sprays for other apple insects and even the calyx spray directed against the codling moth. Although the concentration of lead arsenate in the sprays was not always mentioned, it was inferred that from 3 to 6 pounds for each 100 gallons of water was usually used.

Herms & Ellsworth in 1933 used 36 trees in a light-trap experiment and examined 19,220 apples, both windfalls and picked fruit. The varieties included Yellow Newtown, Skinner Pippin, Hoover, Baldwin, and Ben Davis, and lights of three colors were used in the traps. Among the unsprayed trees the percentages of wormy fruit were as follows: Blue light 50.3, white light 74.2, red light 77.3, and unlighted 73.6.

Eyer's figures on crop injury were based on a few single trees, and included only harvested apples. He commented that the data were variable and inconclusive, but he considered that they showed sufficient promise to warrant further investigation.

Patterson gave tables showing percentages of stung and wormy apples in lighted and unlighted Northern Spy trees for a 4-year period. The lighted trees re-

ceived only the first two cover sprays of lead arsenate. The adjacent unlighted trees received the regular spray schedule of four cover applications in 1933 and 1936 and five in 1934 and 1935. The first year he had one trap in every fourth tree and subsequently a trap in every tree. In 1934, 1935, and 1936 the sprayed blocks showed, respectively, 20.9, 38.8, and 9.1 per cent more injured apples than the lighted blocks. The crops were extremely light in 1934, 1935, and 1936, averaging 400, 700, and 800 apples per tree. Thus, the records might be exceptional because the crops were poor.

Hamilton & Steiner made light-trap experiments at Orleans, Ind., and later Hamilton conducted supplementary experiments at Poughkeepsie, N. Y. At Orleans the experiments were carried on in 5.25 acres of 30-year-old trees located near the center of an orchard. The lighted block was 9 rows wide and 24 rows long in 1934, and 8 rows wide in 1935. Three varities, Jonathan, Rome Beauty, and Winesap, were represented, with a total of 175 suitable trees in the block. In both the check and trap blocks the trees received a full spray program, and were scraped and banded. There was also a large bait-trap block in the orchard. The light traps were suspended in the tops of the trees from overhead cables. Records of worm injury were made on trees uniformly distributed through the check and lighted blocks. Samples of 200 to 500 apples were taken at each drop pick-up and harvest picking. The infestation for each tree was calculated on the basis of injuries found in the samples and the total number of apples represented by the samples. In 1934, the year of the heaviest infestation, the number of worm holes per 100 apples averaged 14 in the lighted trees and 25 in the unlighted trees. In 1935, when the infestation was much lower and both worm holes and stings were counted, the corresponding numbers of injuries were 0.5 and 4.8. At Poughkeepsie the light-trap area consisted of a block of mature trees 4 by 6 rows. This block averaged 18 moths per trap in 24 light traps as compared with 16 moths per trap in a block of 30 baited trees nearby. No records on fruit infestation were made here because of the small infestation.

Collins & Nixon (1930) reported on experiments with the use of light traps against the eye-spotted budmoth, *Spilonota ocellana* (D. & S.), and the fruit tree leaf roller, *Archips argyrospila* (Walk.), at Hilton, N. Y. These experiments formed the basis of the codling moth control work later undertaken by Collins in the same orchard. Most of the following details of these experiments have not been published heretofore.

In 1929 a 4-acre block consisting of 105 large trees was equipped with a water-pan light trap in every tree. The trees were about 53 years old, and included the following varieties: 32 Pound Sweet, 18 Hubbardston, 31 Baldwin, and 24 Twenty-Ounce. The traps were hung close to the trunks of the trees, from large lower branches. The light source in each trap was a 75-watt *Mazda C* lamp suspended over the pan. This original layout of trees and traps was kept intact for 5 years, although variations were tried in other parts of the orchard. In 1930 two additional blocks of approximately the same size as the one already in use were equipped with water-pan light traps. In one block of Twenty-Ounce trees a trap was placed in every second tree in every second row, and in the other (a mixed block of Twenty-Ounce and Alexander) a trap was placed in every fourth tree in every fourth row. During 1930 and 1931 the three lighted blocks were maintained as described above. In 1932 the third block was changed to consist of one trap at the highest possible position in each of 44 trees, these traps being of the electrocuting type and including mercury-vapor tubes and sun lamps as light sources. The traps were operated in this arrangement during 1932 and 1933. An area of about 4 acres between two of the lighted blocks furnished the check trees, which were sprayed according to recommended schedules. In 1932 the one-to-one block with the 44 electrocuting traps was divided into several plats: *A*, 19 lighted trees with no poison spray; *B*, 25 lighted trees sprayed according to schedule with lead arsenate; *C*, 41 trees sprayed according to schedule but not lighted; and *D*, 2 trees that were neither sprayed nor lighted. All the trees in the original one-to-one block with water-pan traps received the regular lead arsenate spray schedule.

Records were thus obtained from 177 lighted trees for 2 years, and from a minimum of 105 trees for 3 additional years.

In 1930 injury records were taken from 100 apples from each count tree, but not all trees were counted. In 1931, 400 apples from each tree, 100 from each quadrant, were examined. In 1932 and 1933, in addition to 400 apples from every tree, the drops from all the trees and all the apples from several trees in each block were examined. Some of the count trees produced as many as 50 bushels.

In 1932, in the original one-to-one lighted block there were 30 per cent more "clean" apples (free from injury) in the lighted trees than in the sprayed checks, and more than twice as many wormy apples and nearly three times as many worm holes in the checks as in the lighted trees. In the block with electrocuting traps the unsprayed trees had 54.9 worm holes and the sprayed trees 18.2 worm holes per 100 apples, whereas in the unlighted plats the unsprayed trees had 111.8 worm holes per 100 apples as compared with 55.4 in the sprayed trees.

Although the light traps were the only direct evident cause of the block variations, it was realized that the use of solid blocks of trees, early shown to be necessary, might have obscured the influence of unknown variables. Therefore, in 1933 another experiment was set up in the Rome Beauty orchard at the New York State Agricultural Experiment Station in Geneva (Parrott & Collins 1934, 1935, Collins & Machado 1937). This was a smaller orchard, its history of infestation was known, the trees were younger, and all orchard operations were under the supervision of the station. The purpose of this experiment was to determine what could be expected of light traps as a control measure and the best methods of setting up further control experiments in commercial plantings; it was carried on 4 years. All the apples, both drops and picks, from each tree were examined and counted each year. Electrocuting light traps, with mercury-vapor or Mazda lamps, were used.

Since during the first season trees having no traps and receiving no spray (true check trees) and trees receiving one cover spray were found to be inferior to trees with light traps alone, such trees were omitted in subsequent years. Seven plats were therefore set up, 4 with light traps and 3 without. One plat containing light traps was not sprayed, and the other 3 received 2, 3, or 4 cover sprays. The same cover sprays were used in the plats that had no light traps. The number of trees per plat ranged from 1 to 10. The trees receiving the different treatments maintained almost exactly the same relative order of worminess (determined by counts of both wormy apples and total worm holes) from year to year regardless of changes in plat layout. Thus, by the analysis each year and by the averages for 4 years, in the sprayed-only plats 4 cover sprays were best, followed by 3 and 2. This fundamental consistency was important, since it showed that the standard controls were of the expected value. The lighted plats followed the same order, and each was considerably less wormy than the unlighted sprayed plat receiving the same number of sprays. The lighted-only plat was always approximately equal to or slightly better than the plat receiving 2 cover sprays, with respect to wormy apples, and considerably better with respect to number of worm holes. This equivalence was correlated with the fact that by the same criteria the lighted plats receiving 2 cover sprays were approximately equivalent to the unlighted plats given 4 cover sprays.

A final test was run in a heavily infested commercial McIntosh orchard, where at least 25 trees could be included in each block. Only one type of light trap and one type of light source were used, together with additional mechanical control measures, such as banding and destruction of caterpillars and removal of drops. This experiment was set up in 1937 with an electrocuting light trap containing a 75- or 100-watt type A *Mazda* lamp in each tree of a solid block of 25 trees. An adjacent block of 25 trees was used as a check. The entire orchard was sprayed by the grower with 5 cover sprays of lead arsenate. In 1938 the original lighted block was the same as in 1937, and 2 additional blocks of the same size and same number of trees were laid out, 1 with both light traps and bait traps and 1 with bait traps only. The bait traps were of the double-container type developed by Steiner. Check trees were selected at random from the remainder of the orchard. In 1939 the trap arrangement in the 3 blocks was the same as in 1938, but in addition all the trees in the remainder of the orchard were baited to stabilize the population. This

system was also carried out in 1940, but with the reversal of the lighted-only and baited-only blocks. Certain details of spraying were varied from year to year, such as applying only 2 cover sprays to some of the trap trees. All the trees were scraped and banded, and the caterpillars as well as the drop apples were removed from the orchard.

The results of these experiments confirmed those obtained in the Rome Beauty orchard—namely, that light traps could cause a reduction in codling moth population and injury equivalent to that obtained by the application of two standard lead arsenate cover sprays. It was found that the population was further reduced when both bait and light were used in the same trees, and that light alone effected a greater reduction than bait alone.

CONCLUSION.—From the experiments summarized in this review the writers conclude that light traps have been tested sufficiently to show that a measurable degree of reduction in codling moth population and injury can be achieved through their use. More detailed knowledge of the habits and behavior of the moths and the development of new light sources and other equipment may render it possible to obtain a greater degree of control. The practical application of light traps in codling moth control must await these further developments.

SUMMARY.—The codling moth has long been known to be attracted to lights, and a number of investigators have studied the possibilities of utilizing this positive phototropic response in the control of the moth by means of light traps. The moth was found to be more strongly attracted to blue and violet light than to other lights, especially to the strong blue and violet bands of the mercury spectrum. The same bands also appear to stimulate oviposition.

The photochemical reactions taking place in the eyes, which result directly or indirectly in the phototropic response, have a morphological manifestation in the movements of the iris-pigment. These reactions proceed more quickly under the influence of blue and violet light—a fact which may account for the greater attractiveness of that region of the spectrum.

The electrocuting type of trap has generally been found to be the most satisfactory. The largest catches are obtained when the traps are hung in each tree close to the top. To obtain measurable reduction in injury it has been found necessary to have a trap in every tree. Traps containing an attractive bait as well as a light capture more moths than either lure alone. When both bait traps and light traps are operated in the same trees, the benefit is greater than with either alone. Light traps have usually given better results than bait traps. The number of females captured by the light traps has been from 28 to 45 per cent, usually 40 to 45 per cent, of the total catch. This was consistently lower than the percentages in bait traps, but the actual number of females caught was usually higher in the light traps. Temperature was an important factor in light trapping, since the codling moth does not fly readily below 60° F.

Light traps have been found to reduce codling moth populations to such an extent as to give a benefit to the fruit which has been evaluated as about equal to two cover sprays of lead arsenate. None of the investigators, however, has recommended that light traps should form a part of a practical control program. Any practical application must await the acquisition of more detailed knowledge of the habits and behavior of the moths and the development of new light sources and auxiliary equipment.—6-12-43.

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Insecticidal Treatment of Market Sweet Corn with High-Clearance Boom Equipment for Control of the European Corn Borer

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Extensive small-plot tests, made with hand sprayers, have been conducted over a period of years near Toledo, Ohio, to determine the most suitable insecticide and application procedure for the control of the European corn borer, *Pyrausta nubilalis* (Hbn.), on market sweet corn. Ground derris root in a spray has proved very satisfactory from the standpoint of both insecticidal effectiveness and plant tolerance.

Tests in commercial fields were therefore begun in 1940 to determine the practicability of applying derris by means of boom sprayers for corn borer control. In all, about 2 acres were sprayed that year. As no commercial sprayer having the necessary 48-inch frame clearance above the rows was available, a special high-clearance, power-operated, horse-drawn, two-row boom sprayers (Fig. 1) was built for these tests. Three nozzles per row were used on a boom which was fastened to a vertical supporting frame and adjustable to the proper height above the corn. No. 3 disks (three-sixty-fourths-inch orifice) were used in the outside nozzles and No. 5 disks (five-sixty-fourths-inch orifice) in the center nozzles. Nozzles were adapted to deliver a solid cone of comparatively coarse spray by drilling a three-sixty-fourths-inch hole through the center of each whirl plate. A pressure of 150 pounds was found to be most satisfactory with these solid-cone-type nozzles. They were arranged to deliver a restricted band of spray (Fig. 1) which resulted in thorough treatment of the areas where the borers feed and much better placement of spray for corn borer control, with less waste, than was possible by use of conventional nozzles producing hollow spray cones.

Newly hatched borers soon seek shelter and feed in spaces between leaf blades in the leaf-whorl, and later in the ear, between the ear and the stalk, and beneath the leaf sheaths. To facilitate the penetration of the spray into these spaces a wetting agent is added to the spray to reduce the surface and interfacial tension. Complete plant coverage is not necessary for successful spraying, but enough spray must be applied to penetrate all the hidden locations where the borers are feeding.

Table 1.—Borer reductions and yields resulting from the application of ground derris, with a boom sprayer, in four varieties of sweet corn in commercial fields near Toledo, Ohio, 1941.

Variety	Number of Borers[1] in—		Per Cent Reduction of Borers in—		Yield[2]	
	100 Plants	Ears from 100 Plants	Plants	Ears	Per Cent Marketable Ears Borer-Free	Per Cent Increase in Borer-Free Ears Over Nontreatment
Spancross						
Treated	155	70	91	89	75	198
Not treated	1653	633	—	—	25	—
Earligold						
Treated	148	32	87	91	89	524
Not treated	1156	352	—	—	14	—
Early Harvest						
Treated	134	38	87	89	78	632
Not treated	1062	332	—	—	11	—
Early Market						
Treated	124	50	87	85	71	308
Not treated	936	328	—	—	17	—

[1] Obtained from plant dissections.
[2] Obtained from grower's harvest.

This usually has been accomplished by the time the spray begins to run off at the base of the plant.

Ground derris, at the rate of 4 pounds per 100 gallons of water, plus 5.3 ounces of wetting agent,[1] was applied 4 times at 5-day intervals, beginning with the earliest hatching of first-generation borers on June 27. In this first season's work, borer populations were reduced 83.6 per cent on the plants and 72.8 per cent in the ears.

These results were so promising that a self-propelled, high-clearance sprayer (Fig. 1) was built and used during 1941. The self-propelled feature permitted positive control of forward travel which, when calibrated with the gallonage per acre, maintained the desired dosage rate. Solid-cone nozzles were used for all spray applications. Six acres were sprayed in 1941, and the results of tests made with this machine in commercial fields on four varieties of corn are given in table 1.

The advantages of these commercial-scale treatments were well illustrated in 1941 by the experience of one grower who harvested 414 dozen ears from one-half acre of treated corn as compared with 175 dozen ears from the same acreage of non-treated corn. The benefits of these treatments were threefold: (1) An increase in number of ears per acre in total marketable yield of sprayed over nontreated corn, because many non-treated ears were damaged so badly as to be unmarketable; (2) an average increase in percentage of borer-free ears harvested, from 16.8 per cent in the untreated to 78.1 per cent in the treated plots; (3) an increase in the average sale price from 15 cents per dozen for untreated to 23 cents for the treated corn whether sorted or not sorted.

In 1942 a combination sprayer and duster was used for the treatment against the first generation of the borer on 9 acres, consisting of four varieties of commercially grown sweet corn. The combination machine was the same self-propelled sprayer used during 1941, with the addition of a dusting unit mounted on the rear of the chassis. The duster feed was accurately calibrated and adjusted to deliver the desired quantities of dust per acre.

The following treatments were made: 4 applications of spray or dust at 5-day intervals, and 2 and 3 applications of spray at 7-day intervals. In the spray treatments, ground derris root containing 4.0 per cent of rotenone, 4 pounds per 100 gallons of water plus the wetting agent (1 part to 2500 parts of water), was applied at a pressure of 150 pounds and at a rate of 150 gallons per acre per applica-

[1] Monobutyl phenylphenol sodium monosulfonate (Areskap).

tion. The dust was prepared by mixing ground derris root with bentonite clay to contain 1.0 per cent of rotenone[1] and was applied at the rate of 40 pounds per acre per application. With 4 applications at these dosages, the total quantities of ground derris used per acre were 24 pounds in the spray and 40 pounds in the dust. Borer reduction data were obtained from dissections made in each replicate for each treatment and are given in table 2.

The ears harvested by the grower at each picking were recorded for each treatment. These were examined for infestation, but very few were classified as unsalable. The ears rejected by the grower as he harvested contributed the bulk of unsalable ears shown in table 2. These were either left on the stalks or thrown to the ground after they were examined. The treated corn was not sorted for market, because the damage caused by borers was so light in all treated ears harvested that the additional cost of sorting was not justified.

The yields in borer-free, infested but salable, and infested but nonsalable ears as shown by the grower's harvest are given in table 2. Total yields for the various treatments in the varieties Spancross and Marcross were not consistent with yields for similar treatments in other varieties. This was due to serious wireworm injury which caused an uneven stand in these two varieties. Since the harvest data were taken from equal linear feet of rows and not from equal numbers of plants, as were the dissection data, this

[1] War Production Board Conservation Order M-133, as amended January 23, 1943, restricts the rotenone content of commercial rotenone dusts to 0.5 per cent.

Table 2.—Borer reduction data obtained from dissections of sweet corn after derris treatments, and yield data obtained from grower's harvest in commercial fields near Toledo, Ohio, 1942.

Varieties and Treatment	Number of Borers in—		Per Cent Reduction of Borers in—		Yield per Acre		
	100 Plants	Ears from 100 Plants	Plants	Ears	Borer-Free Ears	Infested Salable Ears	Infested Nonsalable Ears[1]
Spancross							
4 sprayings at 5 days	308	36	86	86	8800	5745	2392
3 sprayings at 7 days	428	34	81	87	10810	8089	1962
2 sprayings at 7 days	408	50	82	81	7420	8608	2249
4 dustings at 5 days	402	48	82	82	5456	5118	3110
No treatment	2232	266	—	—	2244	8760	5120
Earligold (planted late)							
4 sprayings at 5 days	166	30	85	80	9949	3212	1179
3 sprayings at 7 days	234	28	79	81	7593	4576	1038
2 sprayings at 7 days	332	102	70	31	4575	7594	2358
No treatment	1118	148	—	—	1463	8159	2642
Golden Early Market							
4 sprayings at 5 days	542	100	83	73	9312	4626	1164
3 sprayings at 7 days	726	88	78	76	7230	5612	959
2 sprayings at 7 days	930	118	71	68	5184	5774	1472
No treatment	3262	372	—	—	1542	7225	2911
Marcross							
4 sprayings at 5 days	374	36	82	85	8463	4886	1675
3 sprayings at 7 days	386	46	81	80	8655	5699	1388
2 sprayings at 7 days	532	58	74	75	5932	7704	2392
4 dustings at 5 days	678	84	67	64	4313	6978	2871
No treatment	2062	234	—	—	811	9715	3684
Earligold (planted early)							
4 sprayings at 5 days	500	56	76	78	10582	5072	1181
3 sprayings at 7 days	820	108	60	57	7036	7352	844
2 sprayings at 7 days	1116	168	46	33	5144	5826	2236
No treatment	2062	250	—	—	252	8735	5612

[1] Ears rejected by the grower and left in the field.

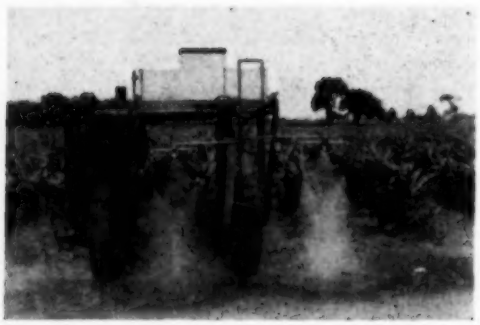

FIG. 1.—Experimental self-propelled, high-clearance, boom sprayer showing solid band of spray which covers the plants, Toledo, Ohio, 1941.

error resulting from uneven stands has been introduced.

An inspection of the data in table 2 brings out the following facts of particular significance. The standard spray treatment of four applications at 5-day intervals was superior to all other treatments when borer reduction in plants was considered. However, three applications at 7-day intervals appeared equal to or slightly better in per cent borer reduction in the ears than the standard treatment in some varieties. This may be attributed to the more favorable timing of one or more of the applications of this treatment with reference to ear infestation. Two applications of sprays at 7-day intervals gave borer reductions equal to or better than four applications of dust applied at 5-day intervals. Spray treatments provided greater numbers of borer-free ears, with 40 per cent less derris per acre, than the dust treatments. Much higher percentages of borer-free ears and much larger total yields of marketable ears were harvested from the sprayed plots than from any untreated plots.

One grower obtained 30 cents per dozen ears for practically all of his treated corn, unsorted, regardless of whether it had received 2, 3, or 4 applications, but received only 10 to 20 cents a dozen for his untreated corn. Approximate gross returns per acre received by this grower were $337 for the sprayed, $263 for the dusted, and $134 for the nontreated corn.

As the equipment used in making these tests was experimental and as the tests were conducted experimentally in commercial fields, it is not possible at present to give accurate figures on such items as cost of equipment, depreciation, labor, etc. It may be stated, however, that the gains realized from both spray and dust treatments in these experiments were far above their cost, and that under conditions where borer populations are high, it should be very profitable to treat market sweet corn for the control of the European corn borer with high-clearance power-operated equipment such as that herein described.—5-29-43.

Effect of the Removal of Squares on Yield of Upland Cotton

E. W. DUNNAM, J. C. CLARK and S. L. CALHOUN,[1] *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

Experiments were conducted at Stoneville, Miss., during 1939, 1940, and 1941 to determine the influence on yield of upland cotton, *Gossypium hirsutum* L., of artificially removing, at weekly intervals for various periods, all squares large enough to attract boll weevils, and of similarly removing given percentages of such squares. Recently developed strains of upland cotton tend to mature a large proportion of bolls from early-formed squares, and with this in mind the writers undertook to obtain information for use in working out a dusting schedule for boll weevil control adapted to the fruiting habits of the early types of cotton grown in the Mississippi Delta.

Related work on this subject has been reported by Hamner (1941), Eaton (1931), and King (1930). At State College, Miss., Hamner found that the removal of all squares soon after they were visible, at weekly intervals for 6 successive weeks, caused no significant reduction in yield of upland cotton. In Arizona Eaton recorded a marked increase in yield of Acala upland and Pima Egyptian varieties of cotton by early defloration. King, also making investigations in Arizona, concluded that in upland varieties the axillary buds usually remain dormant, but that they

[1] Acknowledgment is made of the assistance of Calton Howell, Lloyt R. Faulkner, and Alfred W. Faulk.

[2] In cooperation with the Mississippi Agricultural Experiment Station, Delta Branch, Stoneville, Miss.

can be stimulated to growth at any time in the season by removing the extra axillary buds.

EXPERIMENTAL METHODS.—The first test consisted of removing by hand, at weekly intervals for 1 to 9 weeks, all squares over 6 or 7 days old from cotton dusted with calcium arsenate and from undusted cotton. The dusted plots received nine applications at 5-day intervals, beginning the first week in July and ending by the middle of August. The dust was applied with a rotary hand gun at an average rate of 8 pounds per acre per application.

Squares were removed during the period beginning about June 16 and ending about August 11. In the first plot square removal was discontinued after the first week, in the second plot after the second week, and so on until squares had been removed in the ninth plot for 9 weeks. In case some squares 6 or 7 days old were overlooked, they were removed the following week; therefore, no squares were allowed to develop for more than 13 or 14 days during the defruiting period. Check plots, from which no squares were removed were left in both the dusted and undusted cotton. There were two replications in both 1939 and 1940 and four in 1941.

In 1939 and in 1941, at about 10-day intervals, four records were made of cotton aphid populations by counting the aphids on 1 square inch of the lower surface of the fourth leaf from the top of each plant. For the years 1940 and 1941, following the termination of each defruiting period, counts of squares were made weekly, so that plant response under each condition could be determined.

The second test consisted of removing from undusted cotton at weekly intervals from 10 to 50 per cent of the squares over 6 or 7 days old. In the first plot 10 per cent of the squares were removed each week, in the second plot 20 per cent each week, in the third plot 30 per cent, and so on. In 1939 squares were removed for 7 consecutive weeks, from July 10 to August 22; in 1940 for 11 weeks, from June 19 to August 26; and in 1941 for 9 weeks, from June 20 to August 11. Only squares of suitable age for boll weevil oviposition were considered and no squares were counted or removed that were within approximately 3 days of blooming or were less than 6 days old. Some squares were doubtless counted in two weekly records, but this would also occur in taking weekly boll weevil square-infestation records.

Each season the yield of seed cotton was determined in each plot. In both tests randomized plots 4 rows wide and 10 feet long were used. There were two replications in 1939 and four in 1940 and 1941. Two well-known, high-yielding upland varieties of cotton were used each year, but, as the varieties responded in like manner to the treatments, the results have been combined. Each season the cotton was planted the last week in April, thinned to 1 plant to each 12 inches of row, and given the usual cultural practices. There were no skips in the stand and each plot contained 40 plants, all of which were used for taking records. For the 2 years 1940 and 1941 weekly counts of squares were made after each defruiting period so that the plant response under each condition could be determined.

RESULTS OF REMOVING ALL SQUARES FOR VARIOUS PERIODS.—A summary by

Table 1.—Square removal at weekly intervals for 1 to 9 weeks in dusted and undusted plots.

Weeks Plants Were Defruited	Date Defruiting Was Terminated	Average Number of Squares Removed per Plant per Week							
		Dusted Plots				Undusted Plots			
		1939	1940	1941	Weighted Average	1939	1940	1941	Weighted Average
1	June 16	4.3	1.1	0.5	1.6	3.6	1.0	0.4	1.4
2	23	4.8	1.9	1.3	2.3	4.1	1.6	.9	1.9
3	30	7.1	3.1	3.3	4.2	5.9	3.1	3.3	3.9
4	July 7	8.1	2.9	4.9	5.2	7.0	4.0	4.4	5.0
5	14	10.7	3.4	7.1	7.1	8.0	3.4	7.0	6.4
6	21	11.7	3.8	8.7	8.2	9.9	3.7	9.2	8.0
7	28	11.7	5.1	11.0	9.7	11.5	4.7	10.3	9.2
8	Aug. 4	11.9	5.9	11.9	10.4	11.3	5.3	11.5	9.9
9	11	13.7	5.8	14.4	12.1	12.7	5.6	14.6	11.9

Table 2.—Square production following defruiting periods of 1 to 9 weeks in dusted and undusted plots.

Weeks Plants Were Defruited	Date Defruiting Was Terminated	Number of Squares Produced per Plant per Week					
		Dusted Plots			Undusted Plots		
		1940	1941	Weighted Average	1940	1941	Weighted Average
1	June 16	7.3	12.0	10.4	7.3	11.9	10.4
2	23	7.4	13.8	11.7	6.9	14.0	11.6
3	30	7.7	14.9	12.5	6.4	14.0	11.5
4	July 7	7.1	14.2	11.8	5.9	17.5	13.6
5	14	7.2	14.9	12.3	5.8	14.2	11.4
6	21	7.0	11.8	10.2	6.5	10.9	9.5
7	28	5.8	10.5	8.9	6.5	12.0	10.2
8	Aug. 4	5.4	17.2	13.3	5.8	14.4	11.5
	Check[1]	8.0	10.6	9.7	7.4	10.6	9.5

[1] No defruiting.

years of the records of square removal from dusted and undusted cotton is presented in table 1. Slightly more squares (5.3 per cent) were produced and removed in the dusted than in the undusted plots. Square counts made after defruiting are shown in table 2. The number of squares recorded in dusted and undusted cotton was practically the same.

A record of the total production of squares, including all squares removed and those developing after the various defruiting periods, is presented in table 3. In general, there was a progressive increase in total square production each week. Removing all squares for a period apparently stimulated plant growth and caused the plants to develop new fruiting positions as the season advanced. Practically no axillary buds were stimulated into growth as was reported by King (1930).

It is fully recognized that removing comparatively young squares by hand at weekly intervals would not have quite the same effect as the shedding caused by boll weevil damage to developing squares of a wider age range. Squares in which weevil eggs are deposited remain on the plants 6 to 7 days before they are shed. Thus, under square-removal conditions, plants did not, on an average, develop the fruiting buds to the same stage of maturity that they would have done had the buds been punctured by the boll weevil. Nevertheless, these records should throw some light on the reaction of the cotton plant after the loss of all comparatively large squares.

In 1939 the average aphid population per square inch of leaf area in the undusted check plots was 4.1. The average population in the defruited undusted plots varied little from that of the checks. The average population in the dusted checks was 13.2, or over three times that in the undusted checks, whereas the population in the defruited dusted plots averaged only slightly above that in the checks.

In 1941 the average aphid population in the undusted checks was 4.5 per square inch. As in 1939, the population in the defruited undusted plots varied only slightly from that in the checks. The population in the dusted checks was 20.2 aphids, or over four times that in the undusted checks, whereas that in the defruited dusted plots varied only slightly from that of the checks.

In plots in which all squares were removed for various periods, the aphid populations during the defruiting period were approximately 50 per cent less than on the plots developing fruit—an indication that a physiological change occurred

Table 3.—Total square production in dusted and undusted plots.

Weeks Plants Were Defruited	Date Defruiting Was Terminated	Average Total Number of Squares Produced per Plant per Week			
		Dusted Plots		Undusted Plots	
		1940	1941	1940	1941
1	June 16	8.4	12.5	8.3	12.3
2	23	9.3	15.1	8.5	14.9
3	30	10.8	18.2	9.5	17.3
4	July 7	10.0	19.1	9.9	21.9
5	14	10.6	22.0	9.2	21.2
6	21	10.8	20.5	10.2	20.1
7	28	10.9	21.5	11.2	22.3
8	Aug. 4	11.3	29.1	11.1	25.9
	Check[1]	8.0	10.6	7.4	10.6

[1] No defruiting.

Table 4.—Cotton yield in dusted and undusted plots in which no squares were removed (check) and in which squares were removed weekly for periods of 1 to 9 weeks.

Date Defruiting Was Terminated	Average Pounds of Seed Cotton Produced per Plot							
	Dusted Plots				Undusted Plots			
	1939	1940	1941	Average	1939	1940	1941	Average
June 16	5.16	8.16	5.27	6.20	6.98	6.81	6.60	6.80
23	4.88	7.50	5.84	6.07	6.53	7.16	7.23	6.97
30	4.80	5.97	5.24	5.34	5.65	6.98	6.14	6.26
July 7	4.72	7.91	4.99	5.87	5.42	5.96	6.17	5.85
14	3.11	7.90	3.84	4.95	4.50	6.36	4.31	5.06
21	2.00	6.53	1.68	3.40	3.22	5.98	1.46	3.55
28	1.95	5.77	.90	2.87	4.15	4.33	.84	3.11
Aug. 4	1.16	2.79	.54	1.50	2.08	1.48	.56	1.37
11	1.17	.91	.14	.74	1.81	.62	.22	.88
Check[1]	5.69	6.58	5.56	5.94	7.53	6.58	7.40	7.17

[1] No defruiting.

in the plants when fruit was allowed to set, making them more suitable for aphid development.

YIELDS.—The yield of seed cotton produced in 40-plant plots in which no squares were removed and in similar plots in which squares were removed during various periods is shown in table 4. Despite the fact that more squares were produced and removed from the dusted plots than from those not dusted, and that as many squares developed after defruiting was stopped, less seed cotton was produced in dusted plots than in plots receiving no calcium arsenate. The dusted check plots in which no squares were removed produced an average of 17.2 per cent less seed cotton than those receiving no dust. As the damage caused by boll weevils was of minor importance each year, except in 1941, when weevils entered the plots very late in the season, the reductions can mainly be attributed to damage caused by the increased aphid populations which developed after dusting with calcium arsenate. The reduction in yield in the dusted plots further confirms previous observations that the application of unneeded arsenical insecticides to the cotton plant is a distinct detriment to yield and should be avoided.

To study further the influence of aphids on yield, the number of bolls require to make a pound of seed cotton was determined in 1939. The average for the check plots was 85.5 bolls from dusted plants and 79.2 bolls where no calcium arsenate was applied. The average for the defruited plots was 110.2 bolls from dusted plants and 96 bolls where no calcium arsenate was used. Thus it is indicated that aphids caused a significant reduction in both boll size and yield under all conditions. As would be expected, boll size was decreased as the number of weeks during which all squares were removed was increased.

Apparently the yields depended more on the rainfall during July, August, and September than on any other factor. In 1939, when precipitation totaled 4.21 inches during these months, which was 5.77 inches below normal, the yields of dusted and undusted plants decreased in direct relation to the number of weeks during which the squares were removed. In 1940 a total of 19.50 inches of rainfall, or 9.42 inches above normal, occurred during this period, and yields almost equal to those of the checks were obtained in plots where all squares were removed through July 14 and 21. Conditions were very unsatisfactory for cotton production early in 1940 but late in the season they were good, and if a light frost had not occurred on October 17 and a freeze on November

Table 5.—Average number of squares removed in 10 to 50 per cent defruiting tests and average numbers produced 1939-41.

Per Cent of Squares Removed	Squares Removed per Plant per Week				Squares Produced per Plant per Week
	1939 (7 Weeks)	1940 (11 Weeks)	1941 (9 Weeks)	Weighted Average	
10	0.82	0.63	1.06	0.87	8.70
20	1.74	1.14	1.92	1.63	8.15
30	2.74	1.64	3.13	2.56	8.53
40	3.64	2.17	3.89	3.27	8.18
50	4.55	2.60	4.53	3.89	7.78

14, the other defruited plots would have produced good yields. The year 1941, with 7.78 inches of precipitation, or 2.3 inches below normal during these months, was good for cotton production. In all instances but one where squares had been removed from dusted cotton (for 2 weeks) the yield was less than that of the check.

Analysis of variance of the average yields for the 3-year period shows no significant differences between the yields in the check plots and those in the plots (dusted and undusted) from which all squares were removed for 1, 2, 3, or 4 weeks, but significant reductions in yields resulted from the longer defruiting periods. These results are at variance with those of Hamner (1941), who found no reduction resulting from square removal for 6 weeks, and may be attributed to removal of squares that had developed to a larger size than those he removed, and also to different climatic and soil conditions.

RESULTS OF REMOVING VARIOUS PERCENTAGES OF SQUARES.—In table 5 are summarized the average numbers of squares removed per plant per week for different periods in the years 1939, 1940, and 1941, the weighted averages for the 3 years, and the average number of squares produced per plant per week, when from 10 to 50 per cent of the squares were removed. The weekly removal of 50 per cent or fewer of the squares apparently did not increase square production, as did removal of all squares at weekly intervals for 1 to 8 weeks (table 3).

In table 6 is presented a summary of the yields of seed cotton produced in the plots from which 10 to 50 per cent of the squares were removed. Although good yields were obtained under each treatment, the only instance where more cotton was produced when squares were removed than in the check was in 1940, when 10 per cent of the squares were removed weekly for 11 weeks. The average reduction in yield was directly correlated with the percentage of squares removed and was approximately 0.37 pound per plot for each 10 per cent of squares removed.—8-12-43.

Table 6.—Yield of seed cotton after removal of 10 to 50 per cent of the squares at weekly intervals.

Per Cent of Squares Removed	Pounds of Seed Cotton Produced per Plot				Reduction in Yield (Pounds)
	1939	1940	1941	Average	
0	9.78	6.60	8.25	8.21	—
10	8.52	6.89	8.05	7.82	0.39
20	9.62	5.68	6.80	7.37	.84
30	9.22	5.26	6.78	7.10	1.11
40	8.36	5.56	6.59	6.84	1.37
50	8.78	5.35	5.77	6.63	1.58

SUMMARY.—Experiments conducted at Stoneville, Miss., in 1939, 1940, and 1941, to determine the influence on yield of upland cotton of removing by hand, at weekly intervals for 1 to 9 weeks, all squares over 6 or 7 days old and of removing, at weekly intervals for 7 to 11 weeks, from 10 to 50 per cent of the squares, indicated that the square removal would result in a reduction of yield. The greater square production which followed dusting with calcium arsenate in the absence of an appreciable number of boll weevils was not manifested in increased yield.—8-12-43.

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NEW JERSEY MOSQUITO ASSOCIATION TO MEET

The thirty-first annual meeting of the New Jersey Mosquito Extermination Association will be held at the Hotel Madison, Atlantic City, New Jersey, on March 15, 16 and 17, 1944.

Calcium Arsenate With and Without Cube and Nicotine for Control of the Boll Weevil and the Cotton Aphid, at Tallulah, La., in 1942

M. T. Young, G. L. Garrison, and R. C. Gaines, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Applications of calcium arsenate for control of the boll weevil, *Anthonomus grandis* Boh., are usually followed by an increase in populations of the cotton aphid, *Aphis gossypii* Glov., which may greatly reduce the yield. In certain cases the grade of the cotton may be lowered. Aphids were prevented from increasing to injurious numbers by the addition of 1 per cent of nicotine to all applications of calcium arsentate or 2 per cent of nicotine to alternate applications (Young *et al.* 1942). Cotton aphids have been controlled with a mixture containing 3 per cent of nicotine (Gaines 1942). In experiments during 1942 calcium arsenate was mixed with several aphicides. Cube, nicotine sulfate, and a commercial nicotine dust containing free nicotine were used. Mixtures containing 2 per cent of nicotine were applied at different times of the day.

Plots were either 20 or 22 rows in width and of sufficient length to contain 0.25 acre or more. The plots were arranged in randomized blocks and each treatment, including checks, was replicated five times in each experiment.

Records of yield and of boll weevil and aphid infestations were made on the four center rows (0.05, 0.04, or 0.03 acre) in each plot. The methods of making these records have been discussed previously by the writers (Young *et al.* 1942, Gaines 1942).

Calcium arsentate of the same brand was used whether it was applied alone or in mixtures. It contained 40.5 per cent of total arsenic pentoxide (As_2O_5), 8.7 per cent of water soluble arsenic pentoxide (Geneva method), and 14.7 per cent of free lime. The cube contained 5 per cent of rotenone and 19.9 per cent of total extractives, the nicotine sulfate contained 40 per cent of nicotine, and the nicotine dust contained 10 per cent of free nicotine. The method of making the mixtures and applications has been discussed previously by the writers (Young *et al.* 1942; Gaines 1942).

Applications were made with rotary hand dusters at 4- to 5-day intervals, the number depending upon the degree of infestation and the number washed off by the rain within 24 hours. All blocks received 4 effective applications except Block 5 of Experiment 2, which received 5 effective applications.

In experiment 1 (Table 1), in which the boll weevil infestation was extremely light in all plots, calcium arsenate alone and all mixtures of calcium arsenate with cube, nicotine sulfate, or nicotine dust were equally effective in controlling the weevil. The best aphid control and the highest yield are associated with separate applications of calcium arsenate alone and a mixture of tobacco dust, lime, and nicotine sulfate containing 3 per cent of nicotine (treatment J). Late-afternoon applications of calcium arsenate and nicotine sulfate containing 1 per cent of nicotine (I) gave effective control of the cotton aphid and were followed by a yield somewhat higher than that of the check (A).

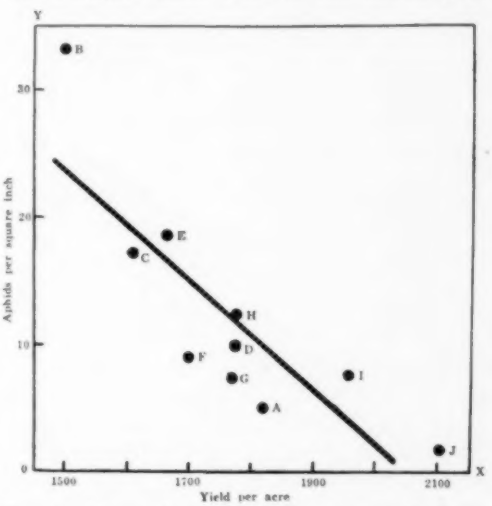

Fig. 1.—Regression of aphids per square inch on yield per acre in experiment 1. Correlation coefficient = −0.84 a highly significant value.

[1] The authors were assisted in the field by M. V. Le Blanc, R. W. Goza, S. C. Bray, and N. W. Thomas. All chemical analyses reported in this paper were made by the Division of Insecticide Investigations of the Bureau of Entomology and Plant Quarantine.

Table 1.—Boll weevil and cotton aphid infestations and cotton yields following various insecticide treatments.

Treatment	Seasonal Average: Squares Punctured by Boll Weevils		Seasonal Average: Aphids per Square Inch	Yield of Seed Cotton per Acre
	Per Cent	*Angle*[1]	*Number*	*Pounds*
Experiment 1				
A—Check	10	18.6	5	1821
B—Calcium arsenate, late afternoon	6	14.4	33	1502
C—Calcium arsenate and cube, 0.5 per cent rotenone, early morning	6	14.0	17	1612
D—Calcium arsenate and cube, 0.5 per cent rotenone, late afternoon	8	16.9	10	1776
E—Calcium arsenate and nicotine sulfate, 0.5 per cent nicotine, late afternoon	6	13.7	19	1665
F—Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine sulfate, 1 per cent nicotine, late afternoon	6	14.5	9	1703
G—Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine sulfate, 2 per cent nicotine, late afternoon	7	15.6	7	1772
H—Calcium arsenate and nicotine dust, 1 per cent free nicotine, late afternoon	6	14.4	12	1777
I—Calcium arsenate and nicotine sulfate, 1 per cent nicotine, late afternoon	6	13.8	8	1955
J—Late afternoon applications of calcium arsenate alone for boll weevil control and of a mixture of tobacco dust, lime, and nicotine sulfate containing 3 per cent nicotine as needed for cotton aphid control	6	14.7	2	2107
Minimum significant difference:				
5 per cent level		—	5	307
1 per cent level		—	7	411
Experiment 2				
A—Check	30	33.5	5	2012
Early morning applications:				
B—Calcium arsenate alone	13	21.1	22	1867
C—Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine sulfate, 2 per cent nicotine	11	19.1	6	2091
D—Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine dust, 2 per cent free nicotine	13	20.7	7	2050
Midday applications:				
E—Same as B	14	22.1	16	1632
F—Same as C	15	23.1	16	1852
G—Same as D	19	25.8	13	1700
Late afternoon applications:				
H—Same as B	14	21.8	17	1707
I—Same as C	16	23.7	5	2115
J—Same as D	16	23.5	5	1933
Minimum significant difference:				
5 per cent level		5.2	6	280
1 per cent level		7.0	9	378

[1] In the transformation of the percentage to angles the square root of the percentage is the sine of the angle.

Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine sulfate containing 2 per cent of nicotine (G) gave a slightly lower aphid count and a slightly higher yield than the similar treatment which contained only 1 per cent of nicotine (F); the differences, however, were too small for significance. Late-afternoon applications of calcium arsenate and cube containing 0.5 per cent of rotenone (D) were more effective against aphids and were followed by a slightly higher yield than early-morning applications (C); the difference in yield, however, was too small for significance. From the plots treated

with the mixture of calcium arsenate and nicotine sulfate containing 1 per cent of nicotine (I) a lower aphid count and a somewhat higher yield were obtained than from the plots treated with the mixture of calcium arsenate and nicotine dust containing 1 per cent of free nicotine (H); the differences, however, were too small for significance. Applications of calcium arsenate alone (B) were followed by the highest aphid infestation and the lowest yield, which, owing to aphid injury, was significantly lower than that of the check (A). The relation between aphid infestation and yield is shown in figure 1.

In experiment 2 (Table 1), in which the boll weevil infestation was light in all plots, a higher infestation of aphids developed in the plots treated with calcium arsenate alone early in the morning (B) than in those treated at either midday (E) or late in the afternoon (H). Alternate applications of calcium arsenate alone and a mixture of calcium arsenate and nicotine sulfate containing 2 per cent of nicotine (C, F, I) gave larger yields than comparable alternate applications of calcium arsenate and nicotine dust containing 2 per cent of free nicotine (D, G, J), but the differences were not significant. Early-morning and late-afternoon applications of both nicotine mixtures (C, D, I, J) gave effective control of aphids as contrasted with the infestations following similar treatments made at midday (F, G); furthermore, the aphid infestations following all three midday applications (E, F, G) were significantly higher than that of the check (A). Calcium arsenate alone and all mixtures were effective against the boll weevil in contrast to the check. Owing to aphid injury, the yields following the applications of calcium arsenate alone were consistently lower than the yield of the check, and in two of the three comparisons the differences were significant. The relation between aphid infestation and yield is shown in figure 2.

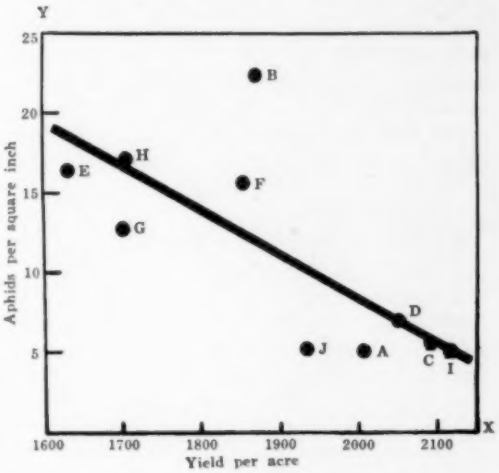

FIG. 2.—Regression of aphids per square inch on yield per acre in experiment 2. Correlation coefficient = −0.73 a significant value.

These two experiments indicate that poisoning with calcium arsenate for a light boll weevil infestation may result in reduced yield unless an aphicide is also used.—6-25-43.

LITERATURE CITED

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ORIENTAL FRUIT MOTH QUARANTINES

Fumigation will be accepted as a condition of entry of host fruits of the oriental fruit moth into Colorado at any time of the year, and into Arizona and Utah during the summer months, under modifications of the quarantines issued June 19, October 25, and September 22, 1943, respectively.

The list of host plants is extended under the Arizona quarantine to include loquat, California evergreen cherry, Catalina cherry, and Carolina cherry, *Cotoneaster parneyi* and *Photinia arbutifolia*. The Utah quarantine includes all but the two latter species. The areas are extended to apply to Kansas, Nebraska, Iowa and to 11 California counties. Of the 9 States having oriental fruit moth quarantines all except Nevada accept fumigation as a condition of entry of used containers of host fruit of the moth.

It is reported that a meeting of the Executive and Uniform Quarantine Committee of the Western Plant Board was scheduled for August 17, 1943, at Reno, Nevada, at which time it was expected that the board would give consideration to the adoption of a uniform quarantine pertaining to the oriental fruit moth.

Field Studies on Insecticides for the Control of the Mexican Fruitfly[1]

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Field experiments to determine the effectiveness of tartar emetic, copper sucrate, and sodium fluosilicate in the control of the Mexican fruitfly, *Anastrepha ludens* Loew, in northern Mexico were designed to permit treatment of data by well established methods of statistical analysis. Although the conclusions determined from the data of one season are valid only for that season, they are believed to be sufficient to indicate the desirability of further studies on the insecticides tested.

Experimental Procedure.—The selection of suitable groves of trees was determined by (1) size and uniformity of trees, (2) similarity of blocks of four plots each of desirable size and shape in each grove, and (3) high population of fruitflies. The several blocks of trees were unavoidably diverse as to size and variety of citrus (Table 1). Each block was divided into four plots as nearly alike as possible. Three of them received applications of insecticides while the fourth one remained untreated. Treatments were assigned to the plots at random.

Table 1.—Summary of number, age, and principal variety of citrus trees in each block.

Block	Age in Years	Number of Trees	
	(Estimated)	Principal Variety	Total
North Washington navel orange grove	25	629	713
South Washington navel orange grove	25	935	1059
Santa Engracia grapefruit grove	16	[1]88	159
El Carmen grapefruit grove	10	[2]144	[3]192
Valencia orange grove	13	692	1018

[1] Marsh seedless variety.
[2] Includes 103 Washington navel orange trees and 41 Marsh seedless grapefruit trees.
[3] Also 11 avocado trees.

The use of glass fly traps furnished a convenient and practical method for measuring fly population over a period of time both before and after applications of insecticides. Traps were suspended within the dense foliage of trees. Traps were hung in both grapefruit and Washington navel orange trees in the plots at El Carmen but in the other plots they were kept only in the trees of the dominant variety, the name of which was used to distinguish each block of trees. One trap was suspended in each of the selected trees in the Valencia block and in both navel orange blocks. Two traps, placed as far apart as possible, were hung in each of the selected grapefruit trees in the grapefruit blocks at Santa Engracia and El Carmen. The identity and exact location of each trap were maintained throughout the season. Traps were confined to trees in a central area in each plot. The number of border rows between the outermost rows of traps and the outer margins of the plots varied in the several blocks and there were at least four border rows in the plots of the South Washington navel orange block and only one border row in plots of the Santa Engracia grapefruit block. All blocks of trees were surrounded by citrus trees.

Each trap was filled almost to the brim of the invaginated part with 290 cc. of solution freshly prepared with 80 g. of crude brown sugar dissolved in 1 liter of water. Traps were allowed to remain in trees for periods ranging from 4 to 8 days, the length of time depending on the occurrence of rain, rapidity of evaporation of the lure, and the number of moths and flies captured. When a trap was taken down for examination of contents, the cork was removed and the contents poured on to a 16-mesh wire screen supported by a heavy wire frame and handle. After removal of fruitflies, the trap was again filled with lure and replaced in its proper position in the tree. Traps were examined in definite order and the examination of all traps in one or more blocks was com-

[1] The work on which this manuscript is based was carried on in the Division of Fruitfly Investigations with the cooperation of the Division of Mexican Fruitfly Control, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture; la Secretaría de Agricultura y Fomento, Mexico; and José Martinez Gomez and Enrique Benitez, proprietors of Hacienda de Santa Engracia and Hacienda El Carmen, respectively.
[2] The authors are indebted to their colleague Donald F. Starr for much assistance on the application of statistical methods of analysis.

pleted on the same day. Two days were required for the examination of the 536 traps in the 5 blocks of trees. Traps were washed when dirty—usually about once a month when large numbers of flies and moths were captured. Care was taken to use similar amounts of water in the washing and rinsing of traps in each plot. This was done in order to have about the same inoculation of wild yeasts in the traps of each plot. Traps were examined previous to spraying of the trees and were allowed to remain empty in the trees while these were being sprayed. As a rule, traps were filled with lure on the day following the termination of spray application in each block.

The insecticides used in these field experiments were as follows: (1) Tartar emetic or potassium antimonyl tartrate, $K(SbO)C_4H_4O_6+\frac{1}{2}H_2O$, commercial grade, powdered. It was used at the rate of 4 pounds in 100 gallons of aqueous solution containing 20 pounds of granulated sugar. Tartar emetic is completely soluble at this dilution. (2) Copper sucrate (Plummer 1938), the formula of which is probably $Cu(OH)_2 \cdot C_{12}H_{22}O_{11}$, prepared with commercial grades of cupric sulfate, sodium hydroxide, and sucrose and the concentrate used at the rate of 4 pounds of dried material in 100 gallons of aqueous solution. This insecticide is partially soluble at this dilution. (3) Sodium fluosilicate, or sodium silico-fluoride, Na_2SiF_6, commercial grade, powdered, used at the rate of 4 pounds in 100 gallons of aqueous solution containing 20 pounds of granulated sugar. This material is completely soluble at the dilution used.

The plan in spraying the 2352 trees of the spray plots was to cover the fruit and foliage with a fine mist, care being taken not to apply amounts that would result in excessive run-off. Application of sprays at a pressure of 400 pounds and with spray guns having a disk opening of .048 inch was most satisfactory and was the usual procedure.

General observations over a period of 4 years have led to the belief that as little as 0.01 inch of rain removed considerable amounts of water-soluble insecticides from the fruit and foliage of trees. Dews were often sufficiently heavy to wet the trees thoroughly. Undoubtedly some of the insecticide was lost in solution when dew dripped from the foliage. As a general practice, trees were sprayed about every 3 weeks if precipitation in excess of 0.02 inch did not necessitate more frequent applications. Traps were examined as soon as possible after cessation of rain, trees were sprayed, and traps were filled with lure. Not infrequently some delay in spraying was occasioned by the muddy condition of groves following irrigation or prolonged rain.

DATA PREVIOUS TO THE APPLICATION OF INSECTICIDES.—Flies were trapped during four trapping periods previous to the application of insecticides in order to determine the uniformity of the population of each block by means of analysis of variance. The fly population was low early in the season, and for this reason records were grouped to eliminate, in so far as possible, the number of zeros appearing in tabulations. The number of traps per group ranged from 3 in the North Washington navel orange block to 6 in the El Carmen grapefruit block (Table 2). To the actual number of flies captured in each group 0.5 was added and the square root extracted. The number 21.88, as given under tartar emetic in line 1 of table 2, represents the sum of the square roots of $n+0.5$ for the 10 groups of fly captures in that plot. The total number of flies was actually 47. The reason this method was followed is that extensive studies by Starr[1] on the capture of Mexican fruitflies in glass fly traps have shown that such data are not distributed normally. Starr followed a method of square root transformation described by Bartlett (1936) and found that skewness of distribution was reduced and more nearly normal departures from a mean were obtained when the square root of the number of flies was extracted. The addition of 0.5 to the number of flies recorded in each group reduced the error that might be introduced through the inclusion of zeros in the tabulation. A summary of data recorded previous to spray application and of the analysis of variance are shown in table 2.

In the analysis of variance (Table 2), tests of significance were made by means of the variance ratio, F (Snedecor, 1940). Significance between periods is to be expected owing to fluctuations in fly populations in citrus groves. Plots were chosen with much care, and homogeneity of fly population might be expected previous to

[1] Starr, Donald F. Unpublished data. 1939.

Table 2.—Summary of numbers of adults of *Anastrepha ludens*, in terms of $\sqrt{n+0.5}$, captured in each plot previous to the application of insecticides.

Period	Sum of Group Captures of Flies, Expressed as $\sqrt{n+0.5}$, in Each Plot				
	Tartar Emetic	Copper Sucrate	Sodium Fluosilicate	Untreated	Total
	North Washington Navel Orange Block (10 groups of 3 traps)				
Oct.					
9–14	21.88	25.33	26.51	26.22	99.94
14–19	22.07	17.69	20.06	22.36	82.18
19–24	23.07	24.51	23.95	24.66	96.19
24–29	22.82	25.09	20.12	23.20	91.23
Total	89.84	92.62	90.64	96.44	369.54
	South Washington Navel Orange Block (10 groups of 4 traps)				
Oct.					
9–14	22.83	33.83	29.06	39.51	125.23
14–19	18.42	27.04	18.93	32.54	96.93
19–24	17.11	24.17	25.64	30.67	97.59
24–29	31.03	35.83	30.23	37.39	134.48
Total	89.39	120.87	103.86	140.11	454.23
Average	22.35	30.22	25.97	35.03	28.39
	Santa Engracia Grapefruit Block (4 groups of 4 traps)				
Oct.					
10–15	11.99	10.99	10.73	9.87	43.58
15–20	9.35	10.24	10.46	11.22	41.27
20–25	7.02	6.15	8.46	7.77	29.40
25–30	6.03	6.80	6.98	9.69	29.50
Total	34.39	34.18	36.63	38.55	143.75
	El Carmen Grapefruit Block (3 groups of 6 traps)				
Oct.					
10–15	5.32	5.32	5.57	8.68	24.89
15–20	4.68	4.39	4.16	5.36	18.59
20–25	3.87	4.68	5.57	4.57	18.69
25–30	6.77	5.66	4.92	7.32	24.67
Total	20.64	20.05	20.22	25.93	86.84
	Valencia Orange Block (6 groups of 5 traps)				
Dec.					
3– 8	11.37	14.84	9.63	9.89	45.73
8–15	14.77	14.08	12.69	14.50	56.04
15–22	16.27	13.22	10.91	14.32	54.72
22–28	13.31	12.24	9.85	10.14	45.54
Total	55.72	54.38	43.08	48.85	202.03
Average	13.93	13.59	10.77	12.21	12.63

Block	Analysis of Variance		
	Mean Square		
	Periods (3 DF)	Plots (Treatments) (3 DF)	Error (9 DF)
North Washington Navel Orange	14.7527	2.1684	3.9169
South Washington Navel Orange	92.1194**	119.7181**	6.8391
[1] South Washington Navel Orange	99.3190**	6.8528	9.2349
Santa Engracia Grapefruit	14.2520**	1.0657	1.2753
El Carmen Grapefruit	3.1441	1.9941	.8766
Valencia Orange	7.9879*	8.3401*	2.0148
[1] Valencia Orange	8.1800*	2.0286	1.9815

[1] Corrected data. * Significant. ** Highly significant.

treatment. Nevertheless, highly significant differences are shown between the number of flies captured in plots of the South Washington navel orange block and significant differences between fly captures in the plots of the Valencia orange block (Table 2). Fortunately, Starr[1] has shown us a method for the correction of data in blocks where differences between plots are significant. This correction removes variations due to differences in fly catch in the several blocks without removing any of the natural variation due to random trapping. The formula is as follows:

[1] Starr, Donald F. Personal communication.

$$x_c = x\left[1.00 - \left(\frac{\bar{x} - \bar{\bar{x}}}{\bar{x}}\right)\left(\frac{s_t - s_e}{s_t}\right)\right]$$

where x_c = the corrected value.
x = the observed value of one period total under one treatment.
$\bar{x}$ = the average value for 4 periods under one treatment.
$\bar{\bar{x}}$ = the average of the block total.
s_t = the standard deviation for treatments, i.e., the square root of the mean square for treatments.
s_e = the standard deviation for periods X treatments (error), i.e., the square root of the mean square for periods X treatments.

Analysis of variance of corrected data gave a variance ratio (F) of 1.35 for data recorded in the South Washington navel orange block and 1.02 for data of the Valencia orange block. Both ratios are close to unity.

DATA AFTER APPLICATIONS OF INSECTICIDES.—The trees in the plots of 4 of the 5 blocks were sprayed between October 31 and December 7, 1938, and in 3 of the 5 blocks between May 20 and June 13, 1939, but trapping records during these periods were omitted from analyses in order that only the trapping data recorded from all 5 blocks between January 4 and April 26, 1939, might be considered. The numbers of flies captured were grouped by traps, 0.5 was added to each group number, and the square root was extracted in the manner followed previous to spraying. Records taken during 11 trap-exposure periods were combined into 6 periods. The same method was followed in all blocks. Fly captures after spray application and analysis of variance for periods and treatments are included in table 3. Highly significant differences between periods are shown in each of the five blocks. Highly significant differences are shown between treatments in 4 blocks and significant differences in one block upon analysis of uncorrected data (Table 3). Correction of data in 2 blocks, using the factors calculated from trap captures previous to spray application, resulted in a change from highly significant to nonsignificant differences between treatments in the South Washington navel orange block. In the Valencia orange block differences between treatments remained highly significant when data were corrected (Table 3). The application of correction factors calculated from data recorded previous to spray application to data recorded after spray application might be questioned and, as pointed out by Wadley,[1] it is desirable not to make corrections or adjustments if the data will answer the questions without it. Data included in table 3 were rearranged as 3 two-way tables and analyzed for 3 criteria (Table 4). The variance ratio, F, for treatments was 21.87, as compared with 4.02, the theoretical value for F at the 1 per cent point of significance. When trap captures in the South Washington navel orange and Valencia orange blocks were corrected, the variance ratio for treatments was 15.53, a value also considerably above the highly significant 1 per cent point of 4.02.

Following the usual procedure, two-way interactions (block-period, etc.) are considered as the discrepance or error for testing the significance of variances of block, period, and treatment. The three-way interaction (block-period-treatment) is used as the discrepance to test the significance of two-way interactions. It is shown in table 4 that there is not only a large variation in periods (period ÷ block-period) but a very definite shift in response to periods from block to block (block-period ÷ block-period-treatment). This would be expected owing, among other factors, to natural variation in fly population within blocks comprised of different varieties of citrus. There is no significant differential effect of period and treatment (period-treatment ÷ block-period-treatment). This is interpreted to mean that relative variation in the plots was about the same and that no "program effect" was brought about by repeated spraying of trees throughout the season. The nonsignificance of the interaction of period-treatment might justify the application of correction factors computed from fly captures recorded previous to spraying to similar data recorded after spraying. Manifestly, there is no certainty that interplot variations in fly population would remain the same at all seasons of the year. The interaction of block and treatment (block-treatment ÷ block-period-treatment) shows a differential in response to treatments from block to block. This would be expected in so far as blocks varied as to size, location, varieties of citrus, and condition and size of trees.

[1] Wadley, F. M. Official communication.

Table 3.—Summary of numbers of adults of *Anastrepha ludens*, in terms of $\sqrt{n+0.5}$, captured in each plot after applications of insecticides.

Period	Sum of Group Captures of Flies, Expressed as $\sqrt{n+0.5}$, in Each Plot				
	Tartar Emetic	Copper Sucrate	Sodium Fluosilicate	Untreated	Total
	North Washington Navel Orange Block (10 groups of 3 traps)				
1	16.98	20.34	20.06	23.20	80.58
2	24.72	24.82	24.70	30.38	104.62
3	19.21	27.60	26.07	29.52	102.40
4	18.79	21.34	21.35	22.62	84.10
5	31.32	40.00	36.23	40.76	148.31
6	18.72	20.61	22.73	23.09	85.15
Total	129.74	154.71	151.14	169.57	605.16
	South Washington Navel Orange Block (10 groups of 4 traps) (Correction factors (not applied here) are as follows:)				
	(1.20566	0.95392	1.07091	0.85575)	
1	16.76	21.45	28.75	27.58	94.54
2	20.91	26.81	33.47	25.56	106.75
3	27.33	41.24	32.33	41.71	142.61
4	25.65	31.53	28.49	30.49	116.16
5	32.43	44.79	41.27	50.19	168.68
6	19.55	24.60	21.53	20.81	86.49
Total	142.63	190.42	185.84	196.34	715.23
	Santa Engracia Grapefruit Block (4 groups of 4 traps)				
1	11.98	18.49	13.69	16.69	60.85
2	26.20	33.76	33.07	29.83	122.86
3	24.89	27.71	34.99	25.68	113.27
4	22.00	23.69	31.49	24.01	101.19
5	40.13	43.23	55.64	45.94	184.94
6	21.47	28.74	27.87	24.89	102.97
Total	146.67	175.62	196.75	167.04	686.08
	El Carmen Grapefruit Block (3 groups of 6 traps)				
1	11.56	12.41	9.99	18.69	52.65
2	36.46	32.29	35.85	44.05	148.65
3	23.95	25.73	28.14	28.94	106.76
4	20.32	18.57	21.93	17.47	78.29
5	40.79	46.55	44.96	49.65	181.95
6	24.34	28.46	28.82	34.29	115.91
Total	157.42	164.01	169.69	193.09	684.21
	Valencia Orange Block (6 groups of 5 traps) (Correction factors (not applied here) are as follows:)				
	(0.95255	0.96408	1.08782	1.01749)	
1	18.15	25.12	21.92	21.31	86.50
2	37.89	52.60	47.31	48.75	186.55
3	35.57	61.40	48.26	53.55	198.78
4	31.81	50.84	50.79	40.91	174.35
5	68.36	95.08	87.59	91.60	342.63
6	38.83	67.82	50.81	63.68	221.14
Total	230.61	352.86	306.68	319.80	1209.95

Block	Analysis of Variance		
	Periods (5 DF)	Mean Square Treatments (3 DF)	Error (15 DF)
North Washington Navel Orange	160.3496**	45.0155**	2.9781
South Washington Navel Orange	241.9301**	100.0281**	14.8903
[1] South Washington Navel Orange	234.9847**	31.8121	10.7909
Santa Engracia Grapefruit	411.0737**	71.7198**	8.7274
El Carmen Grapefruit	545.6455**	40.1639*	7.6409
Valencia Orange	1724.8140**	445.6146**	23.5896
[1] Valencia Orange	1750.9338**	541.7825**	27.4863

[1] Corrected data using factors shown in table. * Significant. ** Highly significant.

It has been shown that the variate of periods was of little importance and analysis of variance is more simplified with its omission. In an analysis involving only blocks and treatment, the variance ratio, F, for the uncorrected data was 6.17. Since this value is greater than 5.95, the theoretical value for F at the 1 per cent point of significance, differences between treatments may be regarded as highly significant. The differences between the mean number of flies in terms of $\sqrt{n+0.5}$ taken in tartar emetic plots and the respective means for the copper sucrate, sodium fluosilicate, and unAlister (1936) in Florida indicated that 6 successive applications of spray composed of 8 pounds of tartar emetic, 5 gallons of molasses, and 100 gallons of water did not injure the foliage of avocado, guava, hog plum, and sugar apple trees. The United States Bureau of Entomology and Plant Quarantine (1935) reported that a spray composed of 8 pounds of tartar emetic and 5 gallons of molasses in 100 gallons of aqueous solution injured trees upon repeated application in Florida but had no ill effect when applied as a mist. It reported later (1937) that 69 applications of sprays prepared by the same formula

Table 4.—Analysis of variance of numbers of adults of *Anastrepha ludens*, in terms of $\sqrt{n+0.5}$, captured in all plots after applications of insecticides. Data of table 3 rearranged as 3 two-way tables for this analysis.

Source of Variation	Degrees of Freedom	Sum of Squares		Mean Square	Variance Ratio (F)
Block	4	9900.7413		2475.1853	
Period	5	11427.7964		2285.5593	
Treatment	3	1279.0655	27,672.4260	426.3552	21.87
Block-Period	20	3991.2681		199.5634	
Block-Treatment	12	828.5603		69.0467	
Treatment-Period	15	244.9944	1,695.9561	16.3330	
Block-Period-Treatment	60	622.4014		10.3733	
Total	119	28,294.8274			

$$\frac{1695.9561}{87}=19.4937 \qquad \frac{426.3552}{19.4937}=21.87$$

treated plots all exceeded 39.33, the theoretical value for the 1 per cent level of significance.

The reduction in fly population apparently brought about by applications of insecticides amounted to 41.2 per cent in tartar emetic plots and 1.6 per cent in copper sucrate plots. In the sodium fluosilicate plots 6.8 per cent more flies were captured than in the untreated plots. It is believed that, under conditions in Santa Engracia, Mexico, and vicinity, where the fly population is sufficiently high in some seasons to cause commercial damage to citrus, a reduction of 41.2 per cent of the flies would not lessen commercial damage an appreciable amount.

EFFECTS OF APPLICATIONS OF TARTAR EMETIC.—Zetek[1] sprayed several mango and citrus trees with sprays containing as much as 40 pounds of tartar emetic in 100 gallons of solution. No burning, yellowing, or shedding of leaves of these trees was noted. Subsequent observations by Mc-

[1] Zetek, James. Unpublished data. 1932.

and applied as a mist had no injurious effects on citrus fruit or trees in Florida. Spencer & Osburn (1938) mentioned that investigators of the United States Bureau of Plant Industry observed burn on citrus fruit when heavy applications of a "washing" tartar emetic spray were applied in periods of scant rainfall. They add that the "droplet" method was found to be the safer procedure. This latter method of application, which is understood to be the same as a mist, has been followed for more than 4 years in Mexico and no foliage or fruit injury has been noticed.

The harmful effect of arsenical sprays on the quality of citrus fruit has been known for many years and has been studied by many investigators. Antimony is closely related to arsenic chemically, and for that reason it is important to know whether applications of tartar emetic would adversely affect the quality of citrus fruits. The quality of citrus fruit is usually indicated by the magnitude of the ratio between the percentage of solu-

ble solids determined by means of a Brix sugar hydrometer and acidity determined as citric acid by titration. The juice of a mature Florida grapefruit, according to Krome (1924), contains not less than 7 parts of soluble solids to each part of anhydrous citric acid. The ratio for early oranges is about 8 to 1. These ratios increase markedly when harvesting of fruit is delayed for several months. Fruit from trees sprayed with arsenicals shows very high ratios. A ratio as high as 124 was included in a publication by Nelson & Mottern (1932). They state that such "heavily sprayed fruit has an acidity of about one-fifth of the normal."

Methods described by Nelson & Mottern (1932) were followed in these studies. The only departure from their methods was that soluble solids and citric acid were determined from samples of the total juice extracted from three fruits picked from one tree.

It appears to be a well-established fact that changes in the composition of fruit take place when arsenical sprays are applied on trees in bloom or when fruit is very small. For that reason it can not be expected that altered composition of fruit would be shown in the spring by tests made on fruit that was mature or nearly mature the previous fall when sprays were first applied. It follows that trees would have to be sprayed for at least two successive seasons before one could expect to detect altered quality of fruit. The average ratios, Brix/acidity, for Marsh seedless grapefruit from trees that had received applications of tartar emetic for as many as two successive seasons and for Valencia oranges that had received applications of the same insecticide for as many as three successive seasons were determined. The ratios for Valencia oranges were all high, 24.1 to 30.2, in 1937 owing to the very ripe condition of the fruit at the time determinations were made. Some variation was shown in the size of ratios from treated and untreated plots but these were so small that they can be considered negligible. It is concluded from these tests that the quality of the fruit was not affected by repeated applications of sprays containing tartar emetic.

SUMMARY.—In field experiments to determine the effectiveness of tartar emetic, copper sucrate, and sodium fluosilicate in the control of the Mexican fruitfly, *Anastrepha ludens* Loew, 5 blocks of citrus trees, consisting of 15 spray plots and 5 untreated plots, were selected and preliminary data on the abundance of fruitflies accumulated by the use of traps previous to the application of the insecticides. Analysis of variance of these data showed that the fly population in the plots of the South Washington navel orange and Valencia orange blocks varied significantly. Data were therefore corrected.

Upon completion of preliminary trapping, every attempt was made to keep tartar emetic, copper sucrate, and sodium fluosilicate on the fruit and foliage of the trees in the spray plots. Analysis of variance of the number of fruitflies, in terms of $\sqrt{n+0.5}$, captured between January 4 and April 26, 1939, showed highly significant differences between treatments. The variance ratio (F) was 21.87 for uncorrected data and 15.53 when the data of the South Washington navel orange block and the Valencia orange block were corrected by factors calculated from fly captures recorded previous to application of insecticides. Both ratios exceeded 4.02, the theoretical value for F at the 1 per cent point of significance.

Analysis of variance showed that there was a large variation in periods and a very definite shift in response to periods from block to block. There was no significant differential effect of period and treatment. The interaction of block and treatment showed a differential in response to treatments from block to block.

The variate of periods was of little importance, and, when omitted, the variance ratio, F, showed highly significant differences between treatments. The differences between the mean number of flies taken in tartar emetic plots and the respective means for copper sucrate, sodium fluosilicate, and untreated plots were all highly significant.

The reduction in fly population, apparently brought about by the applications of insecticides, amounted to 41.2 per cent in the tartar emetic plots and 1.6 per cent in the copper sucrate plots. In the sodium fluosilicate plots 6.8 per cent more flies were captured than in the untreated plots. It is believed that a reduction of 41.2 per cent of the flies would not lessen

commercial damage an appreciable extent in seasons when the fly population is sufficiently high to cause commercial damage.

Evidently the fruit and foliage of citrus trees were not injured by sprays containing tartar emetic when small amounts were applied as a mist.

The quality of Marsh seedless grapefruit from trees that received repeated applications of tartar emetic sprays during two seasons was not affected. This was also true for Valencia oranges from trees that were sprayed with similar sprays for three consecutive years.—8-7-43.

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Toxicity of Nicotine Aerosols to the Green Peach Aphid, Under Greenhouse Conditions

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Attempts to overcome the low volatility of nicotine have resulted in the development of several methods of obtaining a sufficient concentration in air to permit its use as a fumigant. Florists have painted a so-called volatile nicotine concentrate on the heating pipes or have burned piles of slowly combustible nicotine powders or impregnated papers on the walks. Savage (1932) utilized the heat from an internal combustion engine, and Schulz (1922) and McConnell (1937) developed practical methods of handling combustible mixtures. These methods depend on heat for the formation of nicotine vapors and aerosols at a sufficiently high concentration to give a fumigating action. The Savage method requires considerable equipment and is not suited for greenhouse use. The combustible mixture in a pressure can, which is very convenient to use, has largely replaced the older methods. In fumigating with any combustible mixture, however, some of the nicotine is destroyed. What was most desired was a convenient method that would not destroy any of the insecticide.

The liquefied-gas method described by Goodhue (1942) has been shown to be an effective method of producing aerosols of pyrethrum (Sullivan *et al.*, 1942; Billings *et al.* 1942). It can be extended to the use of nicotine to give a very convenient and efficient method with no loss from combustion, and when dichlorodifluoromethane (*Freon 12*) is used as the solvent, the fire hazard attending the heat methods is completely eliminated.

This paper is a report on the toxicity to the green peach aphid, *Myzus persicae* (Sulz.), of nicotine aerosols produced by liberating solutions in dichlorodifluoromethane, and a comparison of the results by this method with those obtained by burning a commercial preparation containing nicotine. The solvent has no insecticidal value.

MATERIALS AND METHODS.—A com-

mercial grade of nicotine analyzing 94.1 per cent was used to prepare the dichlorodifluoromethane solutions. These solutions were held in small containers of about 200 cc. capacity which were fitted with gas-tight valves and liquid-delivery tubes. Each container was equipped with a screw plug in the side which was removed to introduce the nicotine. Monarch-type oil-burner nozzles of the capacity of 1 gallon per hour were attached for spraying. Except for the screw plug, a diagram of this type of apparatus is shown in publications by Goodhue & Sullivan (1942) and by Goodhue (1942).

The solutions were prepared by first introducing the nicotine with a graduated pipette into a clean container through the opening in the side. The opening was closed and the container was attached to a supply of the solvent through a flexible hose. With the container on a balance the required weight of solvent was run in. This technique was fully described by Goodhue & Sullivan (1942).

The combustible mixture used for comparison was a commercial product containing 14 per cent of nicotine by our analysis, and approximately 20 per cent of sodium nitrate and 65 per cent of tobacco stems by the manufacturer's statement. It was packed in a hermetically sealed tin can. The contents of the can were transferred to a fruit jar which was kept tightly closed, except when small samples were removed. The total elapsed time after the opening of the original container was only 3 weeks.

EXPERIMENTAL PROCEDURE.—Collard plants in 4-inch pots and naturally infested with *Myzus persicae* migrating from snapdragon were used in all tests. In the early tests a paper collar was placed around each plant stem below the lowest leaves, on which the aphids could drop during fumigation and from which they were more easily collected than if allowed to drop onto the soil. The plants were then set in shallow pans with sticky banding material around the rim to confine the insects that recovered after being paralyzed. In later tests the paper collar was not used and the plants were placed in a horizontal position so that the aphids dropped directly from the foliage into the pan. The pots rested on a board supported slightly higher than the pan.

The aerosol containers were suspended by a string about 2 feet above the bench in greenhouse units of 1152 cubic feet capacity. The valve was opened by a half turn of a wrench, and the container was given a sudden twist immediately afterward that caused it to rotate during the 2 to 3 minute period of discharge and thereby distribute the material more uniformly through the greenhouse space.

The powder was weighed into a 2-ounce salve box with two quarter-inch holes in the lid. This miniature pressure can was placed on a stand about a foot above the greenhouse bench and ignited with a match, it having been previously found that the sparklers furnished by the manufacturer produced such intense heat that the small quantities of fumigant burned with a blaze and did not produce the desired dense smoke.

The fumigations were begun at 4:30 p.m., and the ventilators were left closed until 8:00 a.m. the following morning. Living aphids were counted at that time and the inactive or partially paralyzed ones were transferred with a brush to a collard leaf in a petri dish resting on moist blotting paper and held in the laboratory. Aphids which recovered settled on the leaves within 2 days, at the end of which time the final counts of living and dead were made. Observations made during the early stages of the fumigations showed that the aphids began to drop from the plant within a few minutes. On the following morning the more susceptible young nymphs were usually inactive, but with sublethal dosages larger nymphs and adults were either moribund or had recovered from the paralytic shock and were walking about. Some of the apparently moribund individuals recovered during the period they were in the petri dish. They were not left in the greenhouse to recover because of the heat and drying effect of the sun.

Where the leaves were resting on the paper collar or two leaves were overlapping with an intervening space of less than a half-inch, many aphids were unaffected by either fumigant. In later tests any overlapping leaves on the plants were separated by use of pins through the stems.

Although tests were made to compare the increased efficiency resulting from the use of a fan, definite information was not obtained with the nicotine and *Freon*

Table 1.—Comparison of reduced dosages of nicotine dissolved in dichlorodifluoromethane and in combustible powder.

	Nicotine in Solvent			Combustible Powder		
Average Temperature	Nicotine Used	Aphids In Test	Aphids Killed	Nicotine in Powder Used	Aphids In Test	Aphids Killed
° *F.*	*Grams per 1000 cu. ft.*	*Number*	*Per cent*	*Grams per 1000 cu. ft.*	*Number*	*Per cent*
A. *Tests at one-half standard dosage, without fan*						
65.3	1.39	712	100	1.27	144	56.9
64.3	1.39	510	95.7	1.27	349	70.1
All tests		1222	97.8		493	63.5
B. *Tests at one-half standard dosage, with fan*						
69.9	1.39	676	99.6	1.27	250	40.8
68.6	1.39	447	100.0	1.27	329	79.3
69.3	1.39	918	99.8	1.27	364	44.8
70.0	1.39	570	97.0	1.27	695	97.1
74.0	1.39	371	99.7	1.27	657	80.5
All tests		2982	99.2		2295	68.5
C. *Tests at one-fourth standard dosage, with fan*						
69.9	.70	522	78.1	.64	437	3.4
72.9	.70	237	74.7	.64	519	71.3
69.7	.70	490	73.1	.64	228	22.7
65.2	.70	219	92.2	.64	659	72.6
68.7	.70	208	87.5	.64	163	12.9
All tests		1676	81.1		2006	36.6
D. *Tests at one-eighth dosage (freon) and one-fourth dosage (powder) with fan*						
66.6	.35	182	70.9	.64	857	66.4
68.0	.35	379	70.2	.64	327	73.4
65.0	.35	306	66.3	.64	384	57.5
67.1	.35	769	88.8	.64	1296	81.0
68.8	.35	416	100.0	.64	304	97.0
All tests		2052	79.2		3186	75.1

solution, but the fan did not cause the material to reach those aphids between contiguous leaves. Fans were used in all later tests, however, since they aided in giving a uniform distribution of the smoke from the powder. When a fan was not used, this material sometimes rose to the greenhouse roof in a narrow column, then descended gradually; at other times it billowed out of the container and over the bench to the floor below.

These experimental tests with the two materials were made in similar greenhouse units and on the same night, so that comparable effects of temperature in the greenhouse and outside weather conditions of moisture and humidity were obtained. In addition, where the comparison was repeated several times, the units were used alternately with each material.

RESULTS.—The preliminary experiments were based on the recommended standard dosage of 1 pound of powder per 25,000 cubic feet or 2.54 grams of nicotine per 1000 cubic feet. Lower concentrations result in kills considerably less than 100 per cent. In 13 preliminary tests on nicotine dispersed by dichlorodifluoromethane, the dosage was successively reduced from 2.54 grams per 1000 cubic feet until a mortality of considerably less than 100 per cent was obtained. One hundred grams of solvent was first used, but later all dosages of nicotine were dispersed in 50 grams of the solution. Nicotine is very soluble in *Freon* and probably much less of that solvent could have been used.

The results of the last four series of tests are shown in table 1. It was intended to have equivalent quantities of

nicotine in the powder and in the dichlorodifluoromethane solution, but final analysis showed that amounts slightly different were actually used.

Five tests were also made to compare the effectiveness of nicotine dispersed by dichlorodifluoromethane with and without a wetting agent. Fifty grams of the solution containing 0.41 gram of nicotine was compared with the same dosage to which 1 gram of diglycol laurate had been added. No change in effectiveness was noted.

DISCUSSION OF RESULTS.—In part B of table 1 the results are given of 5 paired experiments with nicotine fumigation by the two methods, both at half the standard dosage, but with fans operated for 5 minutes to give a uniform distribution of the fumigants. The distribution of the aerosol could not be observed, but the smoke was distributed very uniformly within a minute after evolution. As will be noted in the table, the kill of aphids by nicotine in the solvent was uniformly high, and only 23 individuals survived among the 2982 examined. On the other hand, the kill with powder was variable, and satisfactorily high in only 1 test.

In part C of table 1 the same materials were again compared, with the nicotine at one-fourth the standard dosage. Again the solution gave a fairly uniform and high average kill, whereas that with the combustible powder varied greatly in individual tests and averaged 44.5 per cent less.

On the basis of the average kill of 68.5 per cent with a half dosage of powder (part B, Table 1) and 81.1 per cent (part C, Table 1) by a quarter dosage of nicotine dispersed by the solvent, it appears that the latter was much more efficient than the powder. A further comparison of the two combinations was made in part D of table 1 where a one-eighth dosage of nicotine solution gave a slightly higher average kill than a one-fourth dosage in the powder form. Although in this experiment a comparatively high average kill was obtained with the powder, the results of individual tests varied considerably. The general population of aphids was less resistant in this series, probably because a greater proportion of the insects were in the nymphal stage. Many had developed into winged adults and left the plants, whereas in the earlier tests most adults were wingless forms and remained on the plants.

The results of the experiments led to the conclusion that the burning of the combustible mixture either destroys nearly 50 per cent of the nicotine or fails to evolve it in an effective form. Also, the greater variation in the results with the burning mixture might indicate that the amount of active nicotine produced varies from time to time.

SUMMARY.—The liquefied-gas method of dispersing insecticides has been used to apply nicotine in greenhouse fumigations against *Myzus persicae*. When the nicotine is dispersed in dichlorodifluoromethane only about one-half as much nicotine is required as when it is applied as a constituent of a combustible powder. At the dosages used, the liquefied-gas method also gave more uniform results in numerous replicated tests. No fire hazard is involved.—8-19-43.

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Toxicity Studies of Some Chinese Plants

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Plant insecticides have been used for centuries but the major advances in their study have come in the last twenty-five years. Although inorganic materials can generally be prepared more cheaply in industrial countries, plants may furnish the only source of insecticides available in many areas of China during war conditions. Such plant materials as pyrethrum, tobacco, and rotenone-bearing roots have been important insecticides in United States because they are efficient and less toxic to plants and animals than aresnicals and fluorine compounds. This investigation was undertaken because it seemed to offer possibilities of aid to both China and the United States at a time when insecticide supplies for both countries was a critical problem.

These plant materials were collected by Dr. Shin Foon Chiu, Professor of Entomology at the College of Agriculture, National Sun Yat Sen University, Pingshek, Kwangtung province. They were flown out of Free China by the China National Aviation Corporation and shipped from Hong Kong a few months before the Japanese attack. The collection of plants with detailed notes on habit, habitat, and native uses has been described recently in China by Chiu & Lin (1942). A general discussion and listing of 150 plants of insecticidal interest in China is included. Additional material on the plants dealt with in this paper is available in Lee's (1943) doctoral thesis. Previous short articles have appeared on the two most promising plants, *Millettia pachycarpa* (Chiu *et al.*, 1942), and *Pachyrrhizus erosus* (Hansberry & Lee, 1943).

PREPARATION OF PLANT MATERIALS.—All plant materials were coarsely ground in a Wiley cutting mill. In a few cases extractions were made from these coarsely ground materials. In general, however, the materials were reground in a laboratory Raymond hammer mill which produced a finely divided dust-like material for direct use as an insecticide or for extraction. Extractions were made in a standard soxhlet extractor, ten grams of material being extracted with 100 ml. of solvent for a period of ten hours or longer, depending on the solvent used. The solvent was evaporated on a steam bath and the residue placed in an oven for 3 hours at 95 to 110° C. After weighing, the residue was dissolved or suspended in acetone or acetone and water. The solutions or suspensions were of varying volume, depending on the amount of solvent necessary to suspend or dissolve the residue. These solutions or suspensions were used on the basis of their content of extract, all final spray preparations being made on the basis of dry weight of original plant material. Both ground materials and extracts were placed in the dark in cold storage until used.

TESTING METHODS.—Dusts, water suspensions of the ground plants and extracts were used. The Mexican bean beetle, *Epilachna varivestis* Muls., the silkworm, *Bombyx mori L.*, and the bean aphid, *Aphis rumicis L.*, were depended on for most of the toxicity studies, although some tests were made with the codling moth, *Carpocapsa pomonella* L., the ugly-nest caterpillar, *Cacoecia cerasivorana* (Fitch), the cabbage looper, *Autographa brassicae* (Riley), and the spring canker worm, *Paleacrita vernata* (Peck).

In the use of dusts against the silkworm, dampened leaves were dusted by shaking the plant material onto the leaves from a test tube through silk bolting cloth. After the leaves had dried, larvae were transferred to the dusted leaves and mortality noted after four days. With the first instar Mexican bean beetle larvae groups of insects were dusted in place on the leaf immediately after hatching and while they were still clustered on the egg mass. Mortality was noted after 96 hours.

In spray tests with water suspensions of the ground plant material 2 grams of the sample was suspended in 100 ml. of water and sprayed through a paint spray atomizer. With aphid tests 0.2 per cent sodium lauryl sulfate was used as a wetting agent, except with such roots as *Pueraria yunnaneisis* which contained an active wetting agent, presumably a saponin. Mortality counts were made after 24 hours.

In the codling moth tests, the results of which are not reported in detail here, apples were sprayed with water suspensions at the above concentration, but without the addition of a spreader. Ten eggs in the blackhead stage were placed on each sprayed fruit. Per cent successful entry was noted after seven days.

In testing the extracts, acetone or water-acetone solutions or suspensions were used at such a rate that the final spray contained the extract from 1 g. plant material in 100 ml. water. These final sprays did not contain a constant amount of acetone, but their content was always below 10 per cent, generally less than 5 per cent. In check experiments 10 per cent acetone gave negligible kills. When extracts were tested against the silkworm, mulberry leaves were dipped in the diluted suspension, dried and the insects then placed on the leaves. Mortality was recorded after 4 days.

With aphids the apterous agamic females were sprayed on flannel and transferred to unsprayed nasturtium leaves where mortality was observed the next day. In these tests (but not with the silkworm tests) 0.2 per cent sodium lauryl sulfate was used as a wetting agent.

RESULTS.—Seventeen of the species of plants tested gave less than 50 per cent mortality in any of the tests made. These were: *Antiotrema Dunnianum* (Diels.) H. M., *Buddleia Lindleyana* Fortuna leaves, *Macleaya* (*Bocconia*) *cordata* R. Br. stem, *Cynanchum*[1] sp., *Dendrobium* sp., stem, *Lysimachia foenum-graecum* Hance, *Medicago lupulina* L., *Millettia nitida* Benth. root, *Millettia pulchra* (Benth) Kurz. stem, *Millettia* sp. stem, *Osbeckia crinata* Benth. root, *Polygonum nodosum* Pers., *Rhamnus crenatus* Sieb. & Zucc., stem and root, *Sanguisorbia officinalis* L. root, *Sophora flavescens* Ait. seeds, *Strophanthus divaricatus* (Lour.) Hook & Arn. seed pods and root, and *Wickstroemia nutans* Champ. root. Of these, *M. cordata*, *M. nitida*, *M. pulchra*, *Millettia* sp., *R. crenatus*, *S. flavescens* and *W. nutans* are actually used as insecticides in China. Results here reported are based on initial tests with single collections which may have been lacking in toxicity for a number of reasons. Moreover, in some cases parts of the plant other than those tested are said to contain the most insecticidally active fractions. Thus, although the roots and seeds of *M. cordata* are used as insecticides, only the stems were available for tests. The leaves of the two species of *Millettia* are reported used for insect control, but only stems and roots were tested. The seeds of *Sophora flavescens* were used in these tests, but it is the roots that are used in China.

Plant materials that gave kills above 50 per cent are listed in table 1. With the exception of the two most active materials, *Millettia pachycarpa* and *Pachyrrhizus erosus* seeds, most of the toxicity of these plants seemed to be due to stomach insecticidal action, rather than to any contact effect. The two materials are apparently similar to rotenone-containing roots in their action.

The three species of *Aconitum*, *Delphinium Delavayi*, *Phytolacca acinosa* and *Palaquium* sp. should be investigated more thoroughly, since all of them gave good kills of some stages of some insects. The two materials which gave the best results against the codling moth were the roots of *Tripterygium Forrestii* and the related *Celastrus* sp.

Tripterygium Forrestii had a powerful effect on most insects used. When placed on treated food plants the insects fed for a few minutes, but stopped immediately. They regurgitated, became flaccid and were often reduced to one-third their original size. This condition persisted as long as they were on the treated plants, no further feeding occurring. However, when placed on untreated food they recovered and began normal feeding. At least with the silkworm, the cycle of symptoms could be repeated by placing recovered larvae on dusted food for a second time. The general effect was also noted with the spring cankerworm, the cabbage looper, and the ugly-nest caterpillar.

Some comparative studies of water suspensions and extracts were made with the more promising species. Tables 2 and 3 give data from such tests with the silkworm and bean aphid. The seeds of *Millettia pachycarpa* and *Pachyrrhizus erosus* in water suspension are less toxic than cube to the bean aphid, but some extracts

[1] Although these species were indeterminate from the specimens sent to the United States for insecticidal tests, Chiu and Lin's (1942) paper give the native Chinese names, habit, habitat and exact place collected. It is presumed that collections of the same material could be made and identified later. This is true of all plants mentioned in the present paper.

Table 1. Toxicity of dusts, water suspensions and extracts of some Chinese plants to different instars of the silkworm, first instar Mexican bean beetle, and mature apterous agamic females of the bean aphid.

Material[1]	Silkworm		Bean Beetle		Bean Aphid	
	Number[2]	Per Cent Gross Mortality	Number	Per Cent Gross Mortality	Number	Per Cent Gross Mortality
Aconitum chinense Paxton (root)						
Dust			64	100		
Water susp.					30	0
Alcohol extr. 29.9%	25[5]	0				
Aconitum rillosum Rohb. (entire plant)						
Dust	75[5]	69.3	111	88.1		
Water susp.					30	0
Alcohol extr. 9.9%	25[2]	0				
Chloroform extr. 2.2%	25[2]	0				
Acetone extr. 3.4%						
Ethyl ether extr. 1.5%						
Aconitum sp. (entire plant)						
Dust	75[5]	73.3	108	99.2		
Water susp.					30	0
Alcohol extr. 12.7%	25[4]	0			30	0
Chloroform extr. 3.2%	25[2]	0			30	0
Acetone extr. 5.4%					30	0
Petroleum ether extr. 2.0%					30	3.3
Ethyl ether extr. 0.6%					30	6.7
Carbon tetrachloride extr. 2.5%					30	0
Ardisia crispa var. *Dielsii* Walker (root)						
Dust			78	80.1		
Water susp.					30	6.7
Alcohol extr. 22.9%	25[2]	8.0			30	0
Chloroform extr. 1.8%	25[2]	0			30	0
Arisaema consanguineum Schott. (root)						
Dust	50[5]	12.0	38	58.2		
Water susp.					30	3.3
Arisaema purpureogaleatum Engl. (root)						
Dust	25[5]	8.0	67	56.0		
Water susp.	25[2]	0			30	50.0
Alcohol extr. 3.8%					30	0
Chloroform extr. 1.8%					30	0
Acetone extr. 1.2%					30	0
Celastrus sp. (root)						
Water susp.					30	0
Alcohol extr. 9.4%	25[2]	0			30	0
Chloroform extr. 2.0%	25[2]	0			30	0
Acetone extr. 5.0%					30	0
Centella asiatica (L.) Urban (entire plant)						
Dust	50[5]	4	111	53.7		
Water susp.					30	0
Chloroform extr. 4.0%	25[2]				30	0
Acetone extr. 3.3%					30	0
Delphinium Delavayi Fr. (entire plant)						
Dust	25[5]	16.0	81	94.7		
Water susp.					30	3.3
Alcohol extr. 12.3%	25[2]	0			30	0
Chloroform extr. 2.5%	25[2]	0			30	0
Acetone extr. 3.0%					30	0
Euphorbia Khasiana Baker (root)						
Dust	25[5]	12.0	74	59.4		
Water susp.					30	0
Alcohol extr. 1.4%	25[3]	0			30	0

Table 1.—*Continued*

MATERIAL[1]	SILKWORM		BEAN BEETLE		BEAN APHID	
	Number[2]	Per Cent Gross Mortality	Number	Per Cent Gross Mortality	Number	Per Cent Gross Mortality
Millettia pachycarpa Benth. (root)						
Water susp.					30	100
Alcohol extr. 13.9%	50(2)	32.0				
Chloroform extr. 1.7%	25(2)	0				
Acetone extr. 9.5%	25(2)	0				
Petroleum ether extr. 0.9%	25(2)	0				
Carbon tetrachloride extr. 1.4%	25(2)	0				
Millettia pachycarpa Benth. (stem)						
Dust	25(5)	48	99	96.2		
Water susp.					30	0
Alcohol extr. 9.6%	25(2)	0			30	6.7
Chloroform extr. 1.5%					30	3.3
Acetone extr. 4.2%					30	0
Millettia pachycarpa Benth. (seed)						
Dust	50(5)	100	66	100		
Water susp.					30	100
Alcohol extr. 35.6%	25(5)	24.0				
	50(2)	70.0				
Chloroform extr. 15.4%	25(5)	8.0			30	96.7
	25(2)	36.0				
Acetone extr. 18.3%	25(5)	4.0			30	100
	25(2)	100				
Petroleum ether extr. 13.9%	25(5)	28.0			30	83.3
	25(2)	88.0				
Ethyl ether extr. 13.3%	25(2)	28.0			30	90.0
Carbon tetrachloride extr. 14.5%	25(5)	32.0			30	96.7
	25(2)	56.0				
Millettia pachycarpa Benth. (seed pods)						
Carbon tetrachloride extr. 3.7%	25(2)	16.0			30	0
Pachyrrhizus erosus Urban (seeds)						
Dust	60(5)	100	69	100		
Water susp.					30	100
Alcohol extr. 27.8%	100(2)	100			30	96.0
Chloroform extr. 18.6%	25(5)	84.0			30	100
	25(2)	100				
Acetone extr. 22.8%	25(5)	100			30	100
	25(2)	100				
Petroleum ether extr.	25(5)	100			30	56.7
	25(2)	100				
Carbon tetrachloride extr. 19.4%	25(5)	88.0			30	66.7
Palaquium sp. (seed)	25(2)	92.0				
Dust	75(5)	85.3	79	33.9		
Water susp.					30	0
Alcohol extr. 20.4%	25(2)	0			30	0
Chloroform extr. 3.1%					30	0
Acetone extr. 6.1%					30	0
Petroleum ether extr. 1.8%					30	0
Carbon tetrachloride extr. 3.0%					30	0
Phytolacca acinosa Rcb. (root)						
Dust	50(5)	8.0	107	100		
Water susp.					30	6.7
Alcohol extr. 12.2%	25(2)	0			30	0
Chloroform extr. 2.7%	25(2)	0			30	0
Acetone extr. 3.0%					30	0
Pterocarya stenoptera C. (leaves)						
Dust			60	52.5		
Alcohol extr. 18.4%	25(2)	0			30	0
Chloroform extr. 10.9%					30	0
Acetone extr. 13.2%					30	0

Table 1.—*Continued*

Material[1]	Silkworm		Bean Beetle		Bean Aphid	
	Number[2]	Per Cent Gross Mortality	Number	Per Cent Gross Mortality	Number	Per Cent Gross Mortality
Pueraria yunnanensis Fr. (root)						
Dust	75(5)	52.0	50	27.6		
Water susp.					30	0
Alcohol extr. 13.2%	25(2)	0			30	0
Chloroform extr. 4.2%	25(2)	0			30	0
Acetone extr. 4.5%	25(2)	0			30	0
Petroleum ether extr. 1.0%	25(2)	0			30	0
Ethyl ether extr. 3.3%					30	0
Carbon tetrachloride extr. 3.0%	25(2)	0			30	0
Pueraria yunnanensis Fr. (stem)						
Dust	50(5)	6.0	70	30.5		
Water susp.					30	3.3
Alcohol extr. 12.9%	25(2)	0			30	0
Chloroform extr. 4.8%					30	6.7
Acetone extr. 2.8%					30	3.3
Rhododendron molle G. don (leaves)						
Dust			95	52.3		
Water susp.					30	0
Alcohol extr. 36.4%	25(2)	0			30	0
Chloroform extr. 13.6%	25(2)	0			30	0
Acetone extr. 27.3%					30	0
Rhododendron molle G. Don. (root)						
Dust			90	58.1		
Water susp.					30	3.3
Alcohol extr. 8.6%	25(4)	0			30	0
Acetone extr. 6.8%					30	0
Chloroform extr. 1.5%					30	0
Petroleum ether extr. 0.4%					30	0
Carbon tetrachloride extr. 7.3%					30	3.3
Tripterygium Forrestii Loes. (root)						
Dust	25(5)	0	75	0		
Water susp.					30	0
Alcohol extr. 18.9%	25(5)	0			30	3.3
	25(2)	0				
Chloroform extr. 3.7%	25(5)	0			30	6.7
	25(2)	0				
Acetone extr. 9.8%	25(5)	0			30	6.7
	25(2)	0				
Petroleum ether extr. 2.5%	25(5)	0			30	3.3
	25(2)	0				
Ethyl ether extr. 2.7%	25(2)	0			30	3.3
Carbon tetrachloride extr. 3.5%	25(5)	0				
	25(2)	0				
4 per cent Cube root						
Water susp.					100	100
Alcohol extr. 24.3%	25(5)	56.0			30	100
	75(2)	90.0				
Chloroform extr. 14.3%	25(2)	92.0			30	100
Petroleum ether extr. 10.5%	25(2)	52.0			30	100
Carbon tetrachloride extr. 15.3%	50(2)	74.0			30	100

[1] Water suspensions used at the rate of 2 g. per 100 ml. Extracts used at the rate of extract from 1 g. dry material per 100 ml.
[2] Exponent in parentheses indicates instar used.

of *P. erosus* seeds compare favorably with similar extracts of cube used against the silkworm.

From these limited exploratory tests it is apparent that the plant kingdom offers considerable possibilities for further work in the search for economical and efficient sources of insecticidal materials. Particularly does the rich flora of China offer a fruitful field for investigation. *Millettia*

Table 2. A comparative study of the toxicity of *Millettia pachycarpa* and *Pachyrrhizus erosus* seeds, *Millettia pachycarpa* and cube root to the bean aphid. Water suspensions of the ground material with 0.2 gram sodium lauryl sulfate per 100 ml. spray used in all tests. Mortality adjusted for that in checks (5 per cent); 100 aphids used in each test.

Material	Grams per 100 ml.	Per Cent net Mortality
Millettia pachycarpa (seeds)	1.5	100.0
	1.0	94.7
	0.5	84.3
	0.2	55.7
	0.1	36.5
	0.05	21.5
	0.02	6.3
	0.01	7.3
Millettia pachycarpa (root)	2.0	69.1
	1.5	66.3
	1.0	61.4
	0.5	35.4
	0.2	24.2
	0.1	15.0
	0.05	4.2
Pachyrrhizus erosus (seeds)	1.5	98.9
	1.0	92.6
	0.5	80.2
	0.2	48.4
	0.1	23.6
	0.05	8.6
	0.02	13.6
	0.01	12.6
Cube (root), 4 per cent	0.5	100.0
	0.2	94.7
	0.1	96.9
	0.05	91.5
	0.02	64.4
	0.01	37.6
	0.005	18.2
	0.002	5.2

pachycarpa is already cultivated and used on a moderately large scale there. As soon as world conditions permit shipment of propagating stock, its adaptability to western hemisphere conditions will be fully investigated. *Pachyrrhizus erosus* and related species are indigenous to Latin America where moderately large quantities of seed are available. Botanical, chemical, cultural and toxicological investigations of the genus are proceeding rapidly and results of this work will be made available as fast as conditions permit.

SUMMARY.—Tests with 35 species of Chinese plants reputed to have insecticidal, piscicidal or medicinal value have been made using silkworms, bean beetle larvae or bean aphids. Of these, 18 species killed at least 50 per cent of one or more of the insects tested. *Pachyrrhizus erosus* Urban seems to offer the most promise of being of commercial value because of its annual habit and the fact that the seeds could be gathered in considerable quantity in Latin America where the plant is cultivated for the food value of its tubers. *Millettia pachycarpa* Benth. seeds are also potent insecticides, and seem worthy of experimental propagation for insecticidal purposes. No planting stock of this species is known to be available in the western hemisphere at present. Other species which seem to have sufficient promise to justify further work are *Delphinium Delavayi* Fr., *Tripterygium Forrestii* Loes., *Phytolacca acinosa* Reb., three species of *Aconitum* and unidentified species of *Celastrus* and *Palaquium*.—7-4-43.

Table 3. Per cent mortality of silkworm larvae (mixed instars) feeding on leaves dipped in suspensions of extracts of *Millettia pachycarpa* seeds and roots, *Pachyrrhizus erosus* seeds and cube root. Extract from 1 gr. plant material dispersed in 100 cc. of water with the aid of 5 per cent or less of acetone.

Material	Number	Per Cent Gross Mortality
Millettia pachycarpa (seeds)		
Alcohol extr.	75	47.
Chloroform extr.	50	22.
Acetone extr.	50	52.
Petroleum ether extr.	50	58.
Carbon tetrachloride extr.	50	44.
Millettia pachycarpa (root)		
Alcohol extr.	50	32.
Chloroform extr.	25	0
Acetone extr.	25	0
Petroleum ether extr.	25	0
Carbon tetrachloride extr.	25	0
Pachyrrhizus erosus (seeds)		
Alcohol extr.	100	100.
Chloroform extr.	50	92.
Acetone extr.	50	100.
Petroleum ether extr.	50	100.
Carbon tetrachloride extr.	50	90.
Cube (root)		
Alcohol extr.	100	73.
Chloroform extr.	25	92.
Petroleum ether extr.	25	52.
Carbon tetrachloride extr.	50	74.

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Indirect Hyperparasitism and Observations on Three Species of Indirect Hyperparasites[1]

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In an ecological consideration of hyperparasitism, two distinct types differing in their host relations, should be recognized. Smith (1916) first realized the existence of these types and designated them *direct* and *indirect*. In *direct* hyperparasitism, the searching capacity of the hyperparasite is not influenced by the *unparasitized* hosts of the primary parasite. On the other hand, when hyperparasitism is *indirect*, the possible, as well as the actual, hosts of the primary parasite are searched for by the hyperparasite.

According to Smith (1916), from an economic standpoint, indirect hyperparasites are, as a general rule, less to be feared than are direct hyperparasites.

On the basis of theoretical studies, Nicholson (1933) states that it seems probable that the adverse influence of hyperparasites on the control of pests has been overemphasized, and that the lack of success which has been attributed to the presence of hyperparasites has probably been due to some other cause.

The influence of hyperparasitism on the effectiveness of parasites used in biological control is difficult if not impossible to evaluate. In the laboratory, hyperparasitism may completely eliminate a primary parasite. Only by establishing a hyperparasite in a region where primary parasites are responsible for keeping a pest under control can the influence of hyperparasitism be tested.

It is probable that hyperparasites already present in a region have in some cases prevented, or at least delayed, the establishment of introduced primary parasites. Muesebeck & Dohanian (1927) pointed out that an introduced parasite may be overwhelmed by hyperparasites before it can succeed in firmly establishing itself. This danger is enhanced by the indiscriminate host relations of hyperparasites in general. They considered hyperparasites to be usually less discriminating than primary parasites in their selection of hosts. It is significant that the hosts of hyperparasites are usually more uniform than the hosts of primary parasites, since they are, for the most part, either hymenopterous or dipterous larvae or pupae. The hosts of primary parasites include the egg and the larval and adult stages of most of the insect orders.

In a study of the parasite of *Phytophaga destructor*, Gahan (1933) noted that species of the Platygasteridae, which show considerable discrimination in the selection of hosts, are rarely, if ever, hyperparasitic. The various chalcids, on the other hand, seem to be less selective in the matter of hosts. Although none of the chalcids involved in the complex of hessian-fly parasites are strictly hyperparasitic, many, if not all, will attack and successfully develop at the expense of other parasites, even of their own kind.

The generally indiscriminate host relations of hyperparasites seem to indicate that only rarely will an introduced species do more than replace a native species through competition. It is significant that the introduced primary parasites that have brought about control of a pest are species that are equally successful in their native habitat, in spite of attack by their natural enemies. But, unlike the parasites of introduced pests, the introduced hyper-

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parasite is likely to find all suitable niches occupied. As pointed out by Muesebeck & Dohanian (1927), practically no parasite species of primary rank escapes the attack of hyperparasites. Nevertheless, "the greatest care should be exercised to eliminate any hyperparasites which would form a new element in the local fauna. Obviously the only safe way of doing this is to eliminate them all" (Smith, 1916).

Through lack of knowledge concerning their habits, various species of hyperparasites have occasionally been introduced into Europe and into America. In some instances establishment occurred. Fortunately, however, such introductions do not appear to have had serious consequences.

Haeussler (1940) gives data showing that indirect hyperparasitism of the cocoon of the oriental fruit moth is considerably less important than direct hyperparasitism of the cocoons. He found that hyperparasitization was much greater in cocoons constructed by parasitized caterpillars than in those constructed by unparasitized caterpillars. Apparently, in the latter case the host-finding capacity of the hyperparasites was greatly decreased by the necessity for searching unparasitized cocoons. The fact that indirect hyperparasites, if they occur at all, never become abundant when the host of the primary parasite is attended by ants, indicates that they are relatively deficient in host-finding ability, since the primary parasites may be numerous under such conditions. The primary parasites of the black scale, *Saissetia oleae* (Bern.), are often numerous in ant-attended infestations of the scale, but hyperparasites are comparatively rare in such infestations.

The relation between the black scale parasite *Metaphycus lounsburyi* (How.) and the indirect hyperparasite *Quaylea whittieri* (Gir.) is repeatedly cited as an example of the harm that may result from the introduction of hyperparasites. *Q. whittieri* was liberated and established in California by Craw, in 1901, without any knowledge as to its habits, apparently on the theory that no species of encyrtid was hyperparasitic. Its establishment, however, is said to have had little if any economic effect until the introduction and establishment of *Metaphycus lounsburyi*, 18 years later (Compere 1925). In certain areas where the black scale was plentiful and in suitable condition, *M. lounsburyi* became very abundant. Shortly thereafter, *Q. whittieri* also became very abundant, even outnumbering *M. lounsburyi*.

During 1920 and 1921, the numbers of black scale in certain areas were so greatly reduced by *Metaphycus lounsburyi* that in those areas control was attained. Subsequently, however, the black scale again became numerous enough on citrus to do damage. It seemed obvious that *Quaylea whittieri* was responsible for the ineffectiveness of *M. lounsburyi*. The facts of the case indicate, however, that hyperparasitization by *Q. whittieri* was of no significance. Prior to 1917, the pepper tree, *Schinus molle*, was so heavily infested with black scale that thousands of fine old trees were cut down (Bailey 1917). Such infestations have not occurred since the establishment of *M. lounsburyi*. Apparently, on the pepper tree, *Q. whittieri* does not affect the control of black scale by *M. lounsburyi*. At the present time, in citrus orchards, *Q. whitteri* appears to be one of the *least* abundant of the hyperparasites of *M. lounsburyi*. Since it is an indirect parasite of *M. lounsburyi*, it must explore with its ovipositor the bodies of black scales which may possibly contain *M. lounsburyi*, whether the primary parasite is present or not. It is more restricted in its range than is *M. lounsburyi*. Its life cycle is equal to or longer than that of *M. lounsburyi*, so it has no advantage in rate of reproduction.

The inability of *Metaphycus lounsburyi* to bring about control of black scale on citrus is apparently due to the fact that the life history of the parasite is such that it tends to bring about even development of the broods of scale, with a consequent lack of synchronization, which inhibits parasite reproduction. On the pepper trees, however, the development of the black scale appears to be so uneven that *M. lounsburyi* can exist in controlling numbers (Flanders 1943).

According to Muir (Williams 1931), an introduction comparable to that of *Quaylea whittieri* occurred in relation to the sugarcane leafhopper, *Perkinsiella saccharicida* Kirk., in Hawaii. The encyrtid *Saronotum americanum*, which was introduced into Hawaii from Ohio in 1903 (Timberlake 1919a), proved to be hyperparasitic after the introduction and estab-

lishment of the dryinids *Haplogonatopus vitiensis* and *Pseudogonatopus hospes*, in 1906 and 1907. During the early part of 1906, about 90 per cent of the leafhoppers in a patch of sugarcane were parasitized by dryinids; later in the year, over 90 per cent of these dryinids were parasitized by *S. americanum*. When the leafhopper was brought under control through the introduction of *Cyrtorhinus mundulus* (Bredd.), in 1920, the abundance of dryinids, *relative to that of their host*, increased greatly, whereas *S. americanum* became relatively scarce. Muir (Williams 1931) states that *S. Americanum* is not so capable as the dryinids in finding its host. Consequently, if the dryinids were capable of controlling the leafhopper, *S. americanum* could not prevent their doing so.

The temporarily high population density of the parasite *Metaphycus lounsburyi* (How.), following its establishment on the black scale in southern California in 1919, resulted in a startling increase in the amount of hyperparasitization. Compere (1925) records seven species of hyperparasites that had previously been practically unknown. The two species which he considered most important were the encyrtids *Quaylea whittieri* and *Eusemion californicum*. *Q. whittieri* is the only species known not to be indigenous to California. It is significant that none of these species are included in the hyperparasitic fauna associated originally with *M. lounsburyi*. In Africa, *M. lounsburyi* is attacked by different species of hyperparasites.

When in Australia in 1931, the writer reared the aphelinid-like *Myiocnema comperei* Ashm. under conditions which indicated that *Quaylea whittieri* was its host. If such is the case, *M. comperei* is a true tertiary hyperparasite.

BIOLOGIES OF THREE SPECIES OF INDIRECT HYPERPARASITES.—*Eusemion californicum* Comp., described by Compere (1925) from specimens obtained in the field and reared experimentally on *Metaphycus lounsburyi*, is a secondary parasite of coccids such as *Saissetia oleae* and *Coccus hesperidum* L. It is probably a native of California, occurring most commonly in the cool coastal regions.

Oviposition in *Eusemion californicum*, which seems to occur more readily at 70° F. than at 80° F., is described by Compere (1925) as follows: "The female takes a position on the dorsum of the scale with legs slightly braced and exserts the ovipositor. The length of time taken to oviposit is influenced by the toughness or the resistance which the parasite meets in drilling a hole through the derm of the scale. With the individuals under observation, in some instances five minutes or more was spent in drilling before the ovipositor penetrated for an exploratory examination. After the ovipositor is inserted the parasite works the organ in all directions until satisfied of the presence of a primary larva. When a satisfactory primary host is located, an egg is deposited within its body. If the secondary fails to locate a victim, the ovipositor is withdrawn and the female moves to another scale."

The eggs, according to Compere (1925), "are found floating freely in the body contents of the host. The specimens located by dissection possessed a long stalk, the greater part of which was shriveled and functionless. . . . In one case the shriveled part had separated, leaving a short peduncle in intimate connection with the bulbous enlargement of the egg body. The body of the newly deposited eggs measured 0.2 mm. in length by 0.1 mm. through the greatest width. The body of the ovarian egg is slightly smaller than that of the egg after deposition and possesses a long stalk slightly enlarged at the apex. The stalk is almost twice as long as the body." After deposition, the development of the trophic membrane causes the egg to increase in size.

The larvae, (Compere 1925), "are of the motile type and float freely in the fluid contents of the primary larva. The newly hatched larva possesses a long tail appendage. . . . In this stage the tail is about one-third as long as the head and the body combined. The integument is thrown into folds and the head is very large in comparison with the body. In a more advanced larva the tail appendage was shriveled and was about to be discarded with the next molt. . . . The mature larva does not possess a tail appendage and the head is greatly reduced in proportion to the body. At this advanced stage the primary larva has been almost completely consumed, only the delicate, almost imperceptible integument and the mandibles remaining as evidence of this replacement. . . . The head of the mature larva has several minute pore-like open-

ings in the derm on the under side . . . which serve to distinguish this species from the other inhabitants of the black scale in California."

According to Compere (1925), the pupae are found occupying cells fashioned by the larvae of *Metaphycus lounsburyi* (How.) and are easily distinguished by their general resemblance to the adult. When ready to issue, the adults cast the pupal skin and cut an exit hole similar to that made by *Metaphycus*. An inspection of the scale will readily show whether or not it was inhabited by a *Euseminon*, as the cast pupal skins are very characteristic.

At a temperature of about 82° F., the minimum life cycle of *Eusemion californicum* is 13 days—3 days shorter than that of its host. Embryonic development is completed in slightly less than 2 days if the host larva has voided its meconium. In more immature hosts, the incubation period may be prolonged somewhat. On the third day after egg deposition, the larva undergoes two ecdyses, one of which may occur before it breaks out of the trophic membrane. The third ecdysis occurs on the fourth day after egg deposition. The fourth-instar larva becomes full fed on the fifth day. Pupation occurs on the seventh day. The pupal period is 6 days.

The first-instar larva of *Eusemion californicum* is characterized by having a "tail" bearing several short prongs near the tip. The larva possesses a tracheal loop with short, segmented trachioles. The second instar possesses a pair of sharp highly scleritized mandibles. When a host contains more than one larva of *Eusemion*, the individual in the second instar may destroy those older and younger than itself. Both the second and the third instars possess well-developed tracheal system, without spiracles. The fourth instar has nine pairs of spiracles. Only the second and fourth instars possess scleritized mandibles.

The contents of the host become liquified and are completely consumed by the parasitic larvae. As the host is reduced in volume, the posterior portion of the parasite gradually protrudes from it. Although several larvae may occur in one host, only one larva reaches maturity. Bacterial activity, however, apparently destroys many hosts and, consequently, the parasites within them.

Quaylea whittieri (Gir.) (Encyrtidae) was described in 1918, from one female and one male reared by Alexander Craw from black-scale material collected in Australia in 1901 by George Compere. Several years after taking charge of the California State Insectary, H. S. Smith, in looking over old material reared by Craw, noted that specimens labeled *Hemencyrtus crawi* Ashm. were identical with the species described by Girault. Under the earlier name, Craw (1902) states that he liberated 25 colonies in California. At that time the family Encyrtidae was supposed to be entirely primary in habit.

The fact that *Quaylea whitteiri* was hyperparasitic was not discovered until Quayle & Rust (1911) studied its relation to *Scutellista cyanea*. These authors, however, discussed it under the name *Cerchysius* and apparently believed that it was native to California. Timberlake (1913) stated that it was native and that it was by far the most common secondary parasite of *Coccus hesperidum* Linn. At the present time, *Q. whittieri* appears to be less important than *Cheiloneurus noxius* Comp. as a secondary parasite of black scale.

Primarily, *Quaylea whittieri* is hyperparasitic on the endoparasites inhabiting mature or nearly mature coccids. Its attack on such egg-feeding larva as *Scutellista cyanea* or *Tomocera californica* appears incidental to its search for larva feeding on the body fluids of the scale.

It is recorded as a secondary parasite of *Saissetia nigra* (Nietn.), *S. hemisphaerica* (Targ.), *Coccus viridis* (Green) and *Asterolecanium pustulans* (Ckll.) (Timberlake 1919b). In Australia, the writer reared it from *Coccus* inhabited by *Aneristus ceroplastae*. It seems probable that *Quaylea whittieri* originated in Australia, although its native hosts there are unknown.

In California *Quaylea whittieri* seems limited to the coastal areas, where there are two broods of black scale annually. It apparently has little if any effect on the biological control of scale insects. Although *Metaphycus lounsburyi* is subject to attack, this primary parasite successfully controls black scale on the pepper tree. The ineffectiveness of *M. lounsburyi* on citrus appears to be due to "even-hatch" conditions of the scale and not to hyperparasitism.

Quaylea whittieri is attracted to black scale in the "rubber" stage, or larger, and oviposits in all the larval stages of the primary parasite. The female of *Q. whittieri*, however, can determine the presence of hosts within the black scale only by probing with its ovipositor.

The minimum life cycle of the males of *Quaylea whittieri*, at about 82° F., when developing on *Metaphycus lounsburyi*, is about 16 days, a period equal to the developmental period of the host. The life cycle of the female of *Q. whittieri* probably exceeds that of *M. lounsburyi*, since the life cycle of a female parasite usually exceeds that of the male. Because of the fact that mating did not occur under laboratory conditions, only male development was studied.

The egg incubation period of *Quaylea whittieri* is slightly more than 2 days. There appear to be four larval instars. The first larval ecdysis occurs on the third day after egg deposition, while the larva is still enclosed in the trophic membrane. The second instar is variable in length, depending on the age of the host larva at the time the parasite egg is deposited. The second ecdysis occurs on the fourth day, or at about the time the host larva casts its meconium. The parasite larva becomes full fed and forms a "mummy" or tunica of the host's skin 6 days after egg deposition. The larva of *Q. whittieri* voids its meconium 2 days after mummifying its host. Pupation occurs 9 days after the egg is deposited, or the day following meconial discharge. The pupal period is 7 days. When *Q. whittieri* is developing in *Scutellista*, the life cycle is greatly prolonged, particularly during the last larval instar. The *Scutellista* larva is mummified 16 days after the deposition of the parasite egg.

The ovipositor of *Quaylea whittieri* is long and flexible, and adapted for piercing only delicate membranes. In searching for its host, the female inserts its ovipositor through an opening under the scale margin and then upward, penetrating the soft ventral derm of the scale.

The ovaries of *Quaylea whittieri* are very small in relation to the size of the adult. The ovarian egg likewise is unusually small, although of the double-bodied type. It possesses an extremely long neck, three times the length of the egg proper. The anterior body is narrow and not much wider than the neck. The entire egg is deposited within the host larva. The extreme length of the egg appears to be an adaptation for passing through the long ovipositor.

The first instar is slender, with the thirteenth segment prolonged into a tail. The second instar is more robust and is covered thickly with rounded tubercles. The third instar is without a prominent tail and has a smooth derm. The larval instars, prior to the third ecdysis, lack a tracheal system. The fourth instar, however, has a well-developed tracheal system and nine pairs of spiracles.

Although several larvae of *Quaylea* may inhabit a single larva of *Metaphycus lounsburyi*, only one in each host reaches maturity. After casting its pupal exuvia, the adult parasite cuts its way out through the "mummy" and the dorsum of the dried scale.

The adults of *Quaylea whittieri* are gregarious at times, for they have been observed by Armitage (1922) swarming like gnats on the ends of the new growth at the tops of citrus trees. Armitage suggests that mating occurs at such times.

Myiocnema comperei Ashm. was described in 1900 from seven females and one male reared from black-scale material collected by George Compere in Australia. It is closely related to *Euryischia lestophoni*, a hyperparasite of the puparia of *Cryptochaetum iceryae*. It is significant that the mummies formed by *Quaylea whittieri* closely resemble dipterous puparia.

In a shipment of *Saissetia oleae* collected near Sydney and received at the laboratory in Whittier, California, during the latter part of 1921, the majority of scales had been parasitized by *Metaphycus lounsburyi*, and these in turn, had for the most part, been parasitized by the secondary parasite *Quaylea whittieri*. In addition, about 50 specimens of *Myiocnema comperei* were reared. In 1931, mummies of *Q. whittieri* were removed from several species of *Coccus* collected in Sydney by the writer. These mummies yielded *M. comperei* as well as *Quaylea* and thus indicated that *M. comperei* develops parasitically on the full-fed larva or pupa of *Quaylea* and is, consequently, a tertiary parasite of coccids.

In its native habitat, *Myiocnema comperei* may be a tertiary parasite of *Kermes*

acaciae Mask. Koebele reared *M. comperei* from this coccid, collected at Sydney, New South Wales, in 1899 (Howard 1919).

Smith & Compere (1928) noted that *Myiocnema comperei* mated freely in captivity, and that it, like most hyperparasites of scale parasites, explored the body cavities of the scale hosts. These authors state that small, soft scales, as well as mature individuals, were selected by this parasite. If satisfied with the preliminary inspection with her antennae, the parasite mounted the dorsum of the scale and extruded the ovipositor, which issued at a right angle to the longitudinal axis of the body. If the scale was a mature individual with a tough derm, penetration was effected only after considerable effort. In several cases the time taken to penetrate the derm was 45 seconds; in others, when a soft, immature individual was selected, the entire act occupied about 10 seconds.

A search of the remains of old hosts, from Australia, made with the idea of determining the status of this parasite by dissection, resulted in failure. A second generation of this parasite was not obtained.—6-5-43.

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FEDERAL REGULATIONS MODIFIED

The harvest season under the Mexican Fruitfly quarantine was extended to the close of June 15, 1944, for grapefruit, and throughout the year 1944 for oranges, in the issuance of administrative instructions by the Chief of the Bureau of Entomology and Plant Quarantine in circular B.E.P.Q. 531, dated September 23, 1943.

Administrative instructions to Japanese beetle inspectors on treatment as a basis of certification of articles restricted under the quarantine were issued in circular B.E.P.Q. 529, effective September 10, 1943. This circular supersedes all previous instructions to inspectors on the treatment of plants, fruits, vegetables and soil, under the Japanese beetle quarantine regulations.

In the issuance of circular B.E.P.Q. 530, the date of termination of Japanese beetle quarantine restrictions on fruit and vegetable shipments was advanced to September 8 and on cut flowers the date was advanced to September 30, for the year 1943 only.

A Mosquito Survey of Camp Crowder, Missouri, During 1942

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The 1942 mosquito survey was conducted at Camp Crowder, located in the southwest corner of Missouri, from the latter part of April throughout the year. It was designed to coordinate the necessary control work done in 1942 and to supply information which will serve as a basis for future work. The information obtained deals with the species occurring on the reservation and in the nearby vicinity, their comparative prevalence and the location and nature of their habitats.

The only previous survey of mosquitoes, in which the individual species found at Camp Crowder and their particular breeding places were studied, was that of Captain Stanley J. Carpenter[1] (Report of November 4, 1941 to the Surgeon, Headquarters, 7th Corps Area, Omaha, Nebraska), mosquitoes were collected, and observations were made regarding those most likely to be troublesome. All species found by Capt. Carpenter were again collected in 1942, and many suggestions which he made were useful in the survey.

Future survey work will be helpful, but many of the basic facts concerning local mosquito problems have now been learned. It should be remembered that conditions vary during different seasons so that fluctuations in the densities of species, from season to season, will occur. Rainfall in Neosho from April 1 through October, 1942, was 9.75 inches above normal. For this reason, the 1942 prevalence of species whose breeding is favored by the presence of many puddles is not characteristic of drier seasons. General population trends may now be foreseen, but the work done does not justify the detailed prediction of future mosquito prevalences.

METHODS.—Collections of mosquitoes were made whenever possible, and all developmental stages in the life cycle were taken. Survey trips were made to all parts of the reservation, but emphasis was placed on the cantonment area and adjoining areas, because of the troops concentrated here and the likelihood that either a pest nuisance or transmission of malaria, should it occur, would be of primary importance in the cantonment area. Some collections were made in and about Neosho, Joplin, Monett and other nearby communities, but these constituted a minor part of the survey work. A total of 280 collections of immature mosquitoes was made, 28 of which originated outside of the reservation. Hand collections of adults comprised 108 collections, 34 of which were made outside the reservation. With the exception of two nights during which a light trap was operated in Joplin, all trap operations, totalling 194, were conducted in the cantonment area. A collection is considered as that group of specimens captured at the same time and place, regardless of the number of species involved. Many collections contain several species. The following is a brief outline of the types of collections made:

1. Collections of adults.
   - *a.* Collections made with light traps of the New Jersey type.
   - *b.* Collections made by hand.
     - (1) Collections of active mosquitoes, such as those biting or attempting to bite.
     - (2) Collections of mosquitoes found in daytime (diurnal) resting places or in winter hibernation.
2. Collections of immature stages.
   - *a.* Larvae collected and identified directly, to determine the incidence of various species and the need for current control work.
   - *b.* Larvae or pupae, or both, reared to maturity to furnish adults for a survey collection and for the verification of identifications previously based on larvae.

The following species were taken at Camp Crowder and vicinity:

Anopheles quadrimaculatus Say
Anopheles punctipennis (Say)
Anopheles crucians Wied.
Anopheles barberi Coq.
Culex pipiens L.
Culex quinquefasciatus Say

[1] Now Major Stanley J. Carpenter.

Culex salinarius Coq.
Culex restuans Theob.
Culex tarsalis Coq.
Culex apicalis Adams
Culex erraticus D. & K.
Aedes triseriatus (Say)
Aedes vexans (Meig.)
Aedes atlanticus D. & K.
Aedes canadensis (Theob.)
Aedes trivittatus (Coq.)
Aedes atropalpus (Coq.)
Aedes nigromaculis (Lud.)
Psorophora columbiae (D. & K.)
Psorophora ciliata (F.)
Psorophora howardii (Coq.)
Psorophora ferox (Humb.)
Psorophora cyanescens (Coq.)
Psorophora discolor (Coq.)
Psorophora signipennis (Coq.)
Mansonia perturbans (Walk.)
Theobaldia inornata (Will.)
Uranotaenia sapphirina (O.-S)
Megarhinus septentrionalis D. & K.
Orthopodomyia signifera (Coq.)
Orthopodomyia alba Baker

COLLECTIONS WITH LIGHT TRAPS.—Two light traps became available so that trapping was begun June 18. They were located at distant points within the cantonment area and operated five nights each week, the collections being removed each day. The traps were battery driven, and hours of starting and stopping were regulated by time clocks. Because of mechanical difficulties, there were occasional interruptions in trap operation. Four other traps, these designed for connection with an electric power line, arrived too late in the season for use in 1942. Had they become available sooner, more significant data could have been obtained by trapping. With only two traps available, it was felt that both should be installed in the cantonment area, to give warning of any undue numbers of mosquitoes, especially anophelines, flying about barracks. Accordingly, no trapping in other portions of the reservation was done, though it might have yielded very interesting results.

The number of specimens trapped any one night by one trap varied from none to 89. Because of occasions when no mosquitoes were caught, although proper trap operation occurred, the number of trap collections, 167, is less than the number of trap operations. A list of the species trapped, showing the numbers of each, is given in table 1. Of the 22 species trapped, all except *Psorophora signipennis* were also collected by hand or in the immature stages.

One trap was operated in Joplin on the nights of September 12 and 13. It was located in a garden, surrounded by houses of a residential district. Two specimens of *Anopheles crucians*, the only material of that species collected in connection with the survey, were taken there. The largest single trap collection of *Anopheles quadrimaculatus*, 4 specimens, was made there September 12.

On several occasions, even when stormy weather or high winds were not involved, there was reason to believe that the numbers of trapped specimens of given species were not representative of the numbers present in the immediate vicinity.

In the identification of trapped mosquitoes, the most time-consuming task was the sorting of species of *Culex*. The terminalia of a majority of male specimens of *Culex* were prepared as microscopic mounts, most of them for temporary study only. The study of terminalia was occasionally necessary when species of other genera were involved.

COLLECTIONS MADE BY HAND.—Hand collections of adults are a valuable part of a survey, because they give direct information about the species that are biting in various localities or about those, either active or resting, which are likely to be important. The natural habits of species vary greatly, particularly regarding preferred foods, hours of flight and breeding habits. Much of the information obtainable by field observations is not supplied by trapping.

Table 2 gives the species caught by hand, with a summary of the numbers of specimens. Four of the 23 species were not represented in trap collections: *Aedes canadensis; A. atropalpus; Psorophora ferox; Mansonia perturbans.* Of these, *A. canadensis* and *M. perturbans* were not otherwise encountered during the survey. On the other hand, adults of *Uranotaenia sapphirina* and *Orthopodomyia signifera* were trapped but not caught by hand, though larvae of both were collected.

Much of the importance of hand collections is attached to the various habitats in which they are found. For instance, the finding of species which ordinarily breed

Table 1. Summary of 1942 trap collections at Camp Crowder showing number of specimens captured and number of positive collections.

	Number	June	July	Aug.	Sept.	Oct.	Total
Anopheles quadrimaculatus	Specimens	1	5	17	15	2	40
	Collections	1	4	11	11	2	29
A. punctipennis	Specimens	1		6	4	1	12
	Collections	1		5	4	1	11
Anopheles sp. (damaged)	Specimens				1		1
	Collections				1		1
Culex pipiens	Specimens		5	46	33	26	114[1]
	Collections		5	22	16	17	63[2]
C. quinquefasciatus	Specimens				1		1
	Collections				1		1
C. salinarius	Specimens	35	29	8	21	11	105
	Collections	8	11	7	10	6	42
C. restuans	Specimens	48	194	87	43	7	379
	Collections	13	36	32	14	6	101
C. tarsalis	Specimens			8	152	21	181
	Collections			7	16	12	35
C. apicalis	Specimens					3	3
	Collections					3	3
C. erraticus	Specimens				6	1	7
	Collections				4	1	5
Culex sp. (damaged)	Specimens	3	41	12	11	4	71
	Collections	1	14	10	8	4	37
Aedes triseriatus	Specimens	1		1			2
	Collections	1		1			2
A. vexans	Specimens	31	25	15	32	43	146
	Collections	8	13	12	16	18	67
A. trivittatus	Specimens		5	1	2		8
	Collections		3	1	2		6
A. nigromaculis	Specimens				1	2	3
	Collections				1	2	3
Aedes sp. (damaged)	Specimens		4	3			7
	Collections		2	3			5
Psorophora columbiae	Specimens	8	25	61	189	18	301
	Collections	4	16	18	21	8	67
P. ciliata	Specimens	2		1	3		6
	Collections	2		1	3		6
P. cyanescens	Specimens		3	2	5		10
	Collections		2	2	4		8
P. discolor	Specimens	7	11	19	22		59
	Collections	5	9	12	9		35
P. signipennis	Specimens	1					1
	Collections	1					1
Theobaldia inornata	Specimens				8	50	61[3]
	Collections				2	19	25[4]
Uranotaenia sapphirina	Specimens	1		4	21	2	28
	Collections	1		2	6	2	11
Megarhinus septentrionalis	Specimens					1	1
	Collections					1	1
Orthopodomyia signifera	Specimens		2				2
	Collections		2				2
Unidentified (damaged)	Specimens		10		3		13
	Collections		8		1		9
Total specimens		139	359	291	568	192	1561
Average catch per trap per day		6.32	8.55	8.31	15.77	4.68	8.13

[1] Four in November.
[2] Three in November.
[3] Eight in November.
[4] Four in November.

Table 2. Hand collection of adults showing number of specimens captured and number of positive collections.

	Number	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Anopheles quadrimaculatus	Specimens	6	40		4	3	2	55
	Collections	3	8		3	3	1	18
A. punctipennis	Specimens	4	15	4	49	70	55	199[2]
	Collections	3	5	3	8	3	3	27[2]
Culex pipiens	Specimens				32	13	76	121
	Collections				10	3	5	18
C. quinquefasciatus	Specimens			1				1
	Collections			1				1
C. salinarius	Specimens			1	5	1		7
	Collections			1	1	1		3
Culex, sp., probably *salinarius* (damaged)	Specimens		1					1
	Collections		1					1
C. restuans	Specimens	4			10			16[3]
	Collections		4			3		9[3]
C. tarsalis	Specimens		1	3				4
	Collections		1	1				2
C. apicalis	Specimens	1			1			3[4]
	Collections	1			1			3[4]
C. erraticus	Specimens		107	1	1		1	110
	Collections		5	1	1		1	8
Culex sp., (damaged)	Specimens				1			1
	Collections				1			1
Aedes triseriatus	Specimens	4	4	2				15[5]
	Collections	4	2	2				9[6]
A. vexans	Specimens	3	8	9	42	1		68[1]
	Collections	2	3	4	10	1		25[1]
Aedes sp., probably *atlanticus* (female)	Specimens			1				1
	Collections			1				1
A. canadensis	Specimens							1[4]
	Collections							1[4]
A. trivittatus	Specimens	5	4	54	1			66[3]
	Collections	2	4	4	1			12[3]
A. atropalpus	Specimens	1						1
	Collections	1						1
A. nigromaculis	Specimens			2				2
	Collections			2				2
Psorophora columbiae	Specimens		1	7	4			12
	Collections		1	2	3			6
P. ciliata	Specimens		1	2				3
	Collections		1	2				3
P. ferox	Specimens			18				18
	Collections			4				4
P. cyanescens	Specimens		2	4				6
	Collections		2	4				6
P. discolor	Specimens		120	1				121
	Collections		1	1				2
Mansonia perturbans	Specimens		1					1
	Collections		1					1
Theobaldia inornata	Specimens				13	1		14
	Collections				6	1		7
Megarhinus septentrionalis	Specimens		1					1
	Collections		1					1
Total specimens		28	306	110	163	89	134	848[7]
Total collections		20	36	33	48	12	10	172[8]

[1] Two in April; three in May.
[2] Two in May.
[3] One in May, one in June.
[4] One in June.
[5] Five in June.
[6] One in June.
[7] Two in April, eight in May, eight in June.
[8] Two in April, seven in May, four in June.

in tree holes or those that prefer polluted waters may lead to the discovery of active breeding nearby. Species found flying about in woodland, or in residential or cantonment areas, frequently may be observed for feeding habits, and, if a pest mosquito nuisance exists in the neighborhood, the guilty species determined. *Culex apicalis* and *Theobaldia inornata* are examples of common mosquitoes conspicuous because of its large size and its occurrence in the colder half of the year, when other species are scarce, the latter that are of little importance to man. *Anopheles* adults may be collected by seeking them in customary resting places. During the active season most individuals spend the daytime resting in caves, cellars, hollow trees, beneath bridges and in similar places, while the more protected of these habitats are hibernating quarters in winter. The few resting individuals of *Anopheles quadrimaculatus* collected suggests that the reservoir of the species about Camp Crowder is comparatively small, and this is in agreement with collections of larvae and trapped adults.

The following is a list of habitats in which hand collections of adults were made and the number of collections made in each:

1. Cellars, caves, under cliffs, other resting places	33
2. Woodland	27
3. Roadside, fields, open pasture land	13
4. Outdoors in residential area	10
5. Houses	7
6. Outdoors, about cantonment area	6
7. Near stump or tree holes (Tree hole breeders only)	4
8. Office	3
9. Pigeon lofts	2
10. Car	1
11. Septic tank	1
12. Lighted store windows	1
	108

COLLECTIONS OF IMMATURE STAGES.—The study of breeding places, through the collection of larvae and pupae in their natural habitats, was the most important phase of the 1942 mosquito survey at Camp Crowder. The value of these collections is due to the fact that the most fundamental method of mosquito control is the elimination of breeding places, and a survey that detects them and maps their distribution gets to the root of the problem. Following the inspection of breeding places, suggestions were given to the supervisor of control work, regarding those areas in need of attention. In turn, the effectiveness with which control work was being applied was checked by further search for larvae. Buffalo Creek was examined frequently, because considerable breeding occurred there early in the season and partial pollution by the sewage treatment plant and the close proximity to the cantonment area made it a potential menace.

Collections of immature stages are helpful in the survey of species inhabiting an area, because larvae assist greatly in making identifications. When working with limited facilities for making identifications, the correlation of identifications based on both larvae and adults is extremely valuable. Particularly if all possible types of larval habitats are examined, species may be obtained that seldom are caught by light traps or by hand. Four species, *Anopheles barberi*, *Aedes atlanticus*, *Psorophora howardii* and *Orthopodomyia alba*, were represented during the survey only in larval collections. Excellent adult specimens may be obtained by rearing larvae and pupae to maturity. Those caught in traps are frequently injured, and few males, the terminalia of which are important, are taken by hand except in certain resting places. Specimens from 187 of the 280 collections (66 per cent) were reared to maturity.

A long-handled dipper was used to collect larvae and pupae in the field, except in the case of stumps and tree holes, in which case a rubber suction bulb was usually necessary. Quart jars, labelled as to source of material contained, were carried to the laboratory in a rack such as is used for carrying milk bottles. A convenient rearing cage was arranged by inverting an ordinary lantern chimney over a sponge cup. A small paper cone permitted adults, emerging in the sponge cup, to go up into the chimney but prevented them from falling back into the water. Cheesecloth covered the top of the chimney. After the adults had attained mature coloration and firmness of the body wall, they were killed by introducing a fumigant or were removed by an aspirator and placed in a killing bottle. Records were kept concerning each collection, whether or not rearing was accomplished, emphasis being placed on the nature of the habitat and the number of each species present.

A summary of origin, by habitats, for collections of all species, is as follows:

1. Puddles and small temporary pools	72
2. Small ponds, such as farm stock ponds	20
3. Large ponds	2
4. Fish hatchery ponds	5
5. Natural holes in trees and stumps	36
6. Barrels, cans and other artificial receptacles	27
7. Rock holes in stream bed	4
8. Wells and cisterns	11
9. Marshes and bog-like, flooded fields	6
10. Ditches	33
11. Septic tanks, sewage effluent and polluted ditches	10
12. Small, spring-fed streams	36
13. Larger streams, not directly spring-fed, such as Buffalo and Indian Creeks	18
	280

Because of the adaptation of species to similar or different habitats, as the case may be, the larvae of certain species frequently are taken together, while those of others are seldom if ever associated. It is clear that the species breeding in the holes of hollow stumps and trees will often be found together; less sharply demarked associations occur among puddle breeders and those species characteristic of certain types of ponds. The limited nature of this survey and the wide adaptability of some species to different habitats do not permit many generalizations to be drawn from this phase of the study.

PREVALENCE.—Mosquito biting was never more than a minor nuisance at Camp Crowder in 1942. Occasional biting occurred about the cantonment area and in other parts of the reservation. Biting was most noticeable during the latter half of the season, especially following heavy September rains. There were no known cases of malaria transmission, and the principal vector, *Anopheles quadrimaculatus*, was relatively scarce. Pest mosquitoes were of moderate to considerable importance in several cities within a 30-mile radius.

During June considerable breeding developed in Buffalo Creek, but this was largely eliminated and no further breeding of consequence occurred there. The situation was corrected mainly by oiling and to a lesser extent by channel repair. *Anopheles punctipennis*, *Aedes vexans* and *Culex restuans* were the principal species involved. Very little breeding was found in Indian Creek, relatively few localities along the banks being favorable. Where current was slow and growths of algae had accumulated, *A. punctipennis* sometimes occurred. Bullskin Creek is typical of spring-fed streams, and the water is too cold and favorable localities too few for an important amount of breeding to occur. Just north of Erie, large areas of water cress occur in Bullskin Creek; larvae were collected there several times, but their numbers were not sufficient to be important. Many small streams were dry during the summer, except immediately after rains.

Puddles and small temporary pools were the most important sources of mosquitoes about the cantonment area. Because of the unfinished grounds about many buildings, notably those of the Station Hospital, there were many irregularities of the surface which permitted pools to form at each rain. A large number of Station Hospital buildings had pools beneath them throughout the summer, due to faulty plumbing and uncompleted grading. *Aedes vexans*, *Psorophora columbiae*, *Anophleles punctipennis* and *Culex restuans* were the most important puddle-breeders in the cantonment area. The most conspicuous puddle-breeding occurred in early September, and prompt larvicidal work was necessary to prevent a considerable nuisance. At the time, *Aedes vexans* and *P. columbiae* could be found in clusters, each of several hundred larvae, in numerous puddles about the hospital.

Five characteristic tree hole breeders were found: *Anopheles barberi; Aedes triseriatus; Orthopodomyia signifera; O. alba; Megarhinus septentrionalis.* Of these, *A. triseriatus* is by far the most common, though none of the others except *O. alba* is rare in the area. It was not unusual to encounter biting individuals of *A. triseriatus* near its breeding places, but it was of no practical importance in 1942.

Observations regarding mosquito prevalence in nearby towns were too limited to permit many conclusions. Pest mosquitoes were very troublesome in Monett, and an inspection trip on September 12 disclosed that *Culex pipiens* was the principal species concerned. Larvae and pupae were extremely abundant in the effluent from the municipal sewage disposal plant, many square yards of water surface being covered as if by a blanket. A creek bed carried the effluent, and, except following rains, almost no other water was pres-

ent. Moreover, the performance of the sewage disposal plant was faulty. In Joplin pest mosquitoes were locally abundant and annoying. During the latter half of the summer and early fall, biting was a distinct nuisance in residential areas at evening, *Aedes trivittatus* being the most important species. Mosquitoes were of minor importance in Neosho.

THE GENUS *Anopheles*.—Collections of *Anopheles quadrimaculatus* indicate that it is generally distributed in this area, but it has been found nowhere in large numbers. The most specimens have been taken at the Fish Hatchery in Neosho, where 16 adults were found under a bridge August 4, 1942. Only 4 specimens were taken at the same place on August 13, however. Larvae were collected in the hatchery ponds on 5 occasions, but they occurred only in limited portions of the ponds, were being controlled to a considerable extent by *Gambusia*, and a small to moderate adult population resulted. Larvae were found by U. S. Public Health Service workers in a small private pond of permanent character, located beside railroad tracks about one-third mile northwest of the Fish Hatchery. *A. quadrimaculatus* occurs locally in Joplin, in small to moderate numbers, the principal 1942 collections being from McLellan Park and vicinity. On the Camp Crowder reservation, larvae of *quadrimaculatus* were taken at the following places: On Bullskin Creek, in spring-fed ponds composing part of the stream and located at the rock quarry; from small ground pools in woods north of area 14; from a ditch near the SCRTC motor pool. The latter two habitats were not typical for the species and only occasional specimens occurred. The ponds by the rock quarry are more typical, but the water apparently is too cold to be entirely favorable, and only small numbers were found. Resting adults were taken at six collecting stations on the reservation, two of the stations being caves, the others bridges or buildings. The maximum number of specimens found beneath a bridge at any one time was five, while more than two were never taken in a cave. In September, 1941, Capt. Carpenter found larvae in two small ponds near the hospital and in a pond southwest of the rock quarry. Adults were found at the latter locality in 1942.

It has been shown by Boyd (published reports) that *Anopheles quadrimaculatus* prefers waters distinctly warmer than those in which *A. punctipennis* most frequently occurs, and that an average temperature of 70° F. appears necessary for the rapid development of *A. quadrimaculatus*. This conclusion is borne out by observations at Camp Crowder, and it seems safe to say that most of the waters on the reservation are unsuited to the development of this species in economic proportions. The very few adults discovered in winter hibernation indicate that a relatively small reservoir of the species occurs on the reservation.

Anopheles punctipennis is widely distributed on the reservation and in the surrounding area, and it occurs in a considerable variety of streams, ponds and temporary pools. It tolerates the coolness of spring-fed streams, which comprise a majority of water courses on the reservation. Practically every stream contains at least a few specimens, and hundreds occur in many favorable places. Adult collections indicate, however, that a dense population does not occur. Hibernating adults occur consistently in caves and other suitable shelters, but the maximum degree of concentration encountered is illustrated by the collecting of 53 specimens on about 400 square feet of cave surface by two collectors November 16. In view of the minor role currently assigned to *A. punctipennis* in the transmission of malaria, the economic status of *A. punctipennis* at Camp Crowder appears relatively unimportant.

Trap collections yielded 40 specimens of *Anopheles quadrimaculatus* and only 12 of *A. punctipennis*, but the comparative prevalence of the two species suggested by these scant data is in contrast to that obtained from both hand collections of adults and those of immature stages, showing the unreliability of limited trap collecting.

Anopheles crucians is represented by two adults trapped in Joplin. Both it and *A. barberi* are important in the Camp Crowder area.

THE GENUS *Culex*.—Both *Culex pipiens* and *C. quinquefasciatus* occur at Camp Crowder, their respective ranges of distribution apparently overlapping in this vicinity. Further information is needed regarding the comparative preva-

lence of these closely related species, but in 1942 the former was very common during the latter half of the season, while *C. quinquefasciatus* was uncommon. The tremendous number of *C. pipiens* breeding in sewage effluent at Monett and in sewage-laden water at several Camp Crowder localities are in keeping with the well-known potentialities of the species when favored by pollution. During the fall, *C. pipiens* was very common in wells, cisterns and temporary pools. In winter hibernating quarters, it appeared regularly but in small numbers.

The first species of *Culex* to be found breeding in the spring of 1942 was *C. restuans*. It occurred in a wide variety of habitats throughout the season and more adult specimens were trapped than of any other species. Limited evidence indicates, however, that it was less important as a biter than *C. pipiens*, *Aedes vexans* or *Psorophora columbiae*.

The breeding of *Culex tarsalis* was concentrated mainly in August, September and October, but during that time it was an important inhabitant of puddles and ditches. Several very large trap collections illustrate its temporary abundance. Less important species of *Culex* were *C. salinarius*, *C. erraticus* and *C. apicalis*. All three are well established at Camp Crowder and have been collected consistently, but they are of little significance as pests.

THE GENUS *Aedes*.—*Aedes vexans* is by far the most important species of its genus in the Camp Crowder area. Because of its continued development from spring until late fall and its adaptation to puddles and temporary pools, it is one of the most annoying mosquitoes encountered.

The abundance and pestiferous nature of *Aedes trivittatus* in Joplin suggest that it might be a nuisance at Camp Crowder, should indiscriminate breeding be permitted. Judging from the few references to the species in the literature of Arkansas mosquitoes, the southern limit of economic distribution may be near Camp Crowder.

Aedes triseriatus breeds abundantly in tree holes and stump holes, and it has been taken several times in artificial receptacles. Biting was observed near breeding places, but the species was not important in 1942. Only in cases of troop operations in woodland characterized by numerous breeding places in *R. triseriatus* likely to be a significant pest.

Earlier collecting than was done in 1942 may reveal considerable woodland breeding of *Aedes canadensis*, which is a northern, early spring species. Only one specimen has been taken at Camp Crowder thus far. *A. atropalpus*, found in typical pot holes in the rocky margins of Shoal Creek near Joplin, is of interest principally because of its unusual breeding habits and is of no potential importance at Camp Crowder. *A. atlanticus* and *A. nigromaculis* were rare and of no significance in 1942. The latter is a close relative of the halophilous and very important *A. sollicitans*.

THE GENUS *Psorophora*.—*Psorophora columbiae* is of major pest importance is mainly an inhabitant of puddles, temporary pools and ditches filled with rainwater. Following the heavy September rains, *P. columbiae* and *Aedes vexans* were the chief species developing about the cantonment area, and prompt control measures were necessary to prevent a heavy emergency. The abundance of *P. columbiae* dropped rather abruptly in early October, probably because most eggs destined to develop in 1942 had already been hatched by summer and early fall rains. Other species of *Psorophora* were unimportant. Of the two local species predatory in the larval state, *P. ciliata* and *P. howardii*, the former was relatively uncommon, while the latter was rare. Adults of *P. ferox* and *P. cyanescens* were several times encountered, biting fiercely, but comparatively little breeding occurred. *P. discolor* was found in large numbers on only one occasion. On August 16, hundreds of adults were found in the marginal vegetation of a small temporary pond not far from Joplin. Of 120 specimens taken by sweeping, only two females occurred. About 100 larvae and pupae, the majority being pupae, were collected from the pond. Seventy-two adults emerged, 56 of them (78 per cent) males. It is recorded in literature that the majority of males of *P. cyanescens* have been observed emerging in advance of the females, and the above case of *P. discolor* may be comparable. Only one specimen of *P. signipennis* was collected in 1942.

OTHER GENERA.—*Mansonia perturbans* is represented in survey collections by one specimen taken while biting in Joplin. No breeding has been found. There are few

ponds that seem to be favorable on or near the reservation. Survey work was begun too late in the spring for *Theobaldia inornata* to be found breeding in numbers, but abundant breeding occurred in October and extended in to the winter. Adults were noticed in late September and were conspicuous throughout the remainder of the fall because of their large size, but the species was unimportant. *Uranotaenia sapphirina* is one of the uncommon mosquitoes of no importance at Camp Crowder. It appeared in the light traps on 11 occasions. The only larvae collected were found in company with *Anopheles quadrimaculatus* near Joplin but *sapphirina* undoubtedly breeds on the reservation or nearby.

Megarhinus septentrionalis is a beneficial species, though of little practical value. The adults do not suck blood, while the larvae are predators on the larvae of their own and other species. *M. septentrionalis* is a typical inhabitant of tree holes but is not uncommon in artificial receptacles such as cans. Rearing accomplished in 1942 shows that nearly full-grown larvae frequently require 6 weeks or more to mature, and that one larva may consume several dozen fullgrown larvae of *Aedes triseriatus* or species of comparable size over a period of weeks. The retarded development of larvae in the fall and their occurrence in natural habitats in January suggest that *septentrionalis* winters at least partially in the larval stage in southwestern Missouri. Both *Orthopodomyia signifera* and *O. alba* are characteristic members of the tree hole and stump hole fauna, the former being moderately common and the latter rare. *O. alba* has not previously been collected in the Middle West, according to published records.

OTHER SPECIES.—It is probable that further collecting will add several species to the list of mosquitoes known to occur in the Camp Crowder area, though none is likely to be of much importance. *Anopheles walkeri* Theob. may occur in marshes containing aquatic vegetation, though habitats on the reservation are scarcely typical. More attention to collecting in nearby communities may disclose the presence of *Aedes aegypti* (L.), the principal vector of yellow-fever and a characteristic domestic species. Several other species of *Aedes*, all rare, if present at all may also occur here. The same is true of *Psorophora varipes* (Coq.) and *P. horrida* (D. & K.) An attempt to locate pitcher plants (*Sarracenia* spp.) was made in 1942, with the hope of finding *Wyeomyia smithii* (Coq.) which breeds in the water contained in these plants, but both field observations and consultations with local botanists were unsuccessful.

SUMMARY.—Methods followed in the 1942 mosquito survey at Camp Crowder, Missouri and the results obtained are discussed in the present report. Thirty-one species have been taken on the reservation or in the vicinity, 26 being collected from larval habitats. The most prevalent have been *Anopheles punctipennis*, *Culex pipiens*, *C. restuans*, *Aedes vexans* and *Psorophora columbiae*. *Anopheles quadrimaculatus* is established in the area, but the number of favorable breeding places on or near the reservation is limited and the resulting population relatively small. *Aedes aegypti* has not been collected. Pest species originating in puddles, temporary pools and ditches are among the most important mosquito problems encountered in 1942 and likely to occur in the future.—7-13-43.

Dr. M. A. Stewart, associate professor of parasitology at the University of California, has been elected president of the Pacific Coast Entomological Society. Dr. E. Gordon Linsley, assistant professor, has been reelected secretary. (*Science*)

Dr. Guy F. MacLeod, professor of entomology at the University of California, has been appointed chief of the chemicals and fertilizer branch of the Chemical Division of the War Food Administration. (*Science*)

SCIENTIFIC NOTES

Toxicity of Thiourea and Phthalonitrile to Housefly Larvae

E. R. McGovran and P. G. Piquett, *U. S. D. A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The control of the breeding of houseflies is important at all times and is especially important in the protection of military personnel and the civilian population under war conditions. With this in mind, laboratory tests were made with a number of the more potent new insecticides to determine their toxicity to housefly larvae.

Sodium fluosilicate has been used to control fly larvae by Sanders (1942). Hellebore, borax, calcium cyanamid, and superphosphate have been suggested to kill fly larvae in manure (Bishopp 1939).

Of the newer materials found toxic to insects, thiourea was reported toxic to larvae of *Lucilia sericata* (Meig.) by Hoskins *et al.* (1940), and phthalonitrile was reported toxic to a number of leaf-feeding insects by Swingle *et al.* (1941). Thiourea is soluble in water, whereas phthalonitrile is practically insoluble.

The fly larvae, *Musca domestica*, L., were reared on a modification of the formula published by Eagleson (1937). The eggs were placed on a mixture of 248 gm. of crushed oats, 15 ml. of syrup, 125 mg. of dried brewer's yeast, and 235 ml. of water. The mixture was placed in a 6-inch battery jar and allowed to stand for 3 days. One ml. of housefly eggs[1] suspended in 10 ml. of water were then poured on the surface of the medium. Active third instars that were nearly full-grown were taken from this medium and used in the tests.

The test materials in powdered form were added to approximately 23 gm. of oats in a 150-ml. beaker and thoroughly mixed. Thirty milliliters of a mixture of 125 mg. of brewer's yeast, 15 ml. of syrup, and 235 ml. of water was added to each beaker. Each beaker was then infested with from 50 to 200 larvae. The larvae were reared and the tests were made at 75° F. and 70 per cent relative humidity. The infested beakers were covered with cloth and held until all surviving insects had emerged. The adults that emerged were counted and the percentage of mortality was calculated.

Borax was included as a basis for comparison of the toxicity of the other materials. The results are given in table 1.

Table 1.—Mortality of housefly larvae in an artificial medium treated with insecticide.

Concentration of Insecticide Used	Mortality Caused by Thiourea	Mortality Caused by Phthalonitrile	Mortality Caused by Borax
Per Cent by Weight	*Per Cent*	*Per Cent*	*Per Cent*
0.224	—	—	100
0.112	100	100	81
0.050	99	68	0
0.028	96	53	—
0.014	86	0	—
0.007	9	—	—

[1] The authors wish to thank J. H. Fales for supplying the eggs used to rear the larvae for these tests.

These data show that under the conditions of these tests thiourea, phthalonitrile, and borax ranked in the order named in toxicity to the larvae. The first two materials caused 100 per cent mortality at one-half the concentration of borax that caused an equal mortality. Thiourea at 0.014 per cent killed approximately the same percentage of larvae as borax did at 8 times this concentration.—9-10-43.

Summary.—In laboratory tests on third instars of *Musca domestica*, thiourea and phthalonitrile were found to be highly toxic to this insect when added to the larval medium.—9-10-43.

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Two Foreign Bean Pod Borers Discovered in Texas

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Epinotia opposita Hein.—In December 1941 the pods of green string beans in several localities in the southern part of the lower Rio Grande Valley of Texas were found to be attacked by the larvae of an olethreutid moth. Reared adults were determined by Carl Heinrich as *Epinotia opposita* Hein., a species not heretofore recorded from the United States. Larvae were also noted in string beans in April and December 1942. No infestation was observed in the spring of 1943; however, an exhaustive survey was not made.

This species was described by Heinrich (1931) from alfalfa and cowpeas at Lima, Peru. Adults have also been reared from larvae feeding in string beans originating in Mexico. The collection in the United States National Museum contains additional specimens from Guatemala, Costa Rica, Chile, and Argentina, those from the last-named country having been reared from *Vicia faba*. Brucher (1941) states that *Epinotia opposita* Hein. was observed as a pest of string beans in Chile since 1932 and damaged 50 per cent of the production in Quillota in 1940–41, although the usual extent of injury is from 10 to 20 per cent of the marketable yield.

Maruca testulalis (Geyer).—Adults reared from larvae found feeding in the pods of string beans in the vicinity of Olmito, Tex., in the lower Rio Grande Valley, in June 1943 were determined by Carl Heinrich as this species. At the time this pest was discovered no other green string beans were growing in the valley; however, the larva was not found in two fields of lima beans located about 25 and 50 miles, respectively, from the field where the infesta-

tion was observed. A limited survey also failed to reveal the presence of the pest in *Crotalaria incana*, a recorded wild host in Puerto Rico, found growing near the beach at Boca Chica, Tex. This well-known pest of leguminous pods is distributed throughout the tropical and subtropical world, but heretofore it has not been recorded from the continental United States.—11-1-43.

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Insecticidal Tests with *Phellodendron amurense* Extractive and Several of Its Fractions

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In a brief note on the insecticidal properties of the fruit of *Phellodendron* spp. (*amurense* Rupr.), Haller (1940) reported that preliminary results obtained with the nonvolatile portion of the fruit extractive against mosquito and codling moth larvae and adult houseflies were sufficiently promising to warrant further studies with this material. Roark (1939), in a discussion of agricultural products as insecticides, had previously mentioned these findings. Chemical studies of the principle responsible for the insecticidal action and results with houseflies and goldfish have already been published (Schechter & Haller 1943). The present paper gives the results of entomological tests with petroleum ether extracts of the fruit and several of its fractions.[1]

PRELIMINARY TESTS.—The initial tests with an ether extract of the fruit were made against culicine mosquito larvae by a method described by Campbell *et al.* (1933). At a concentration of 10 parts per million this extract in acetone solution gave 62 per cent kill in 18 hours. Derris containing 5.2 per cent of rotenone used at the same concentration gave only 6 per cent kill.

FRACTIONATION TESTS.—A chemical fractionation of one lot of the extract was undertaken, and each fraction was tested in acetone solution against the housefly, *Musca domestica* L., by the turntable method. Certain fractions were tested also against larvae of the codling moth, *Carpocapsa pomeonlla* (L.),[2] but these tests did not give such sharp differentiation as did those against flies. The fractionation scheme used, together with the relative toxicity to houseflies obtained with each fraction, is outlined in the accompanying diagram. The rating of each fraction is based on two tests, in which the concentration was 50 milligrams per milliliter of acetone. It will be seen that some of the fractions are much more highly toxic than the original extract. The most highly toxic fraction is fraction B of the molecular distillate.

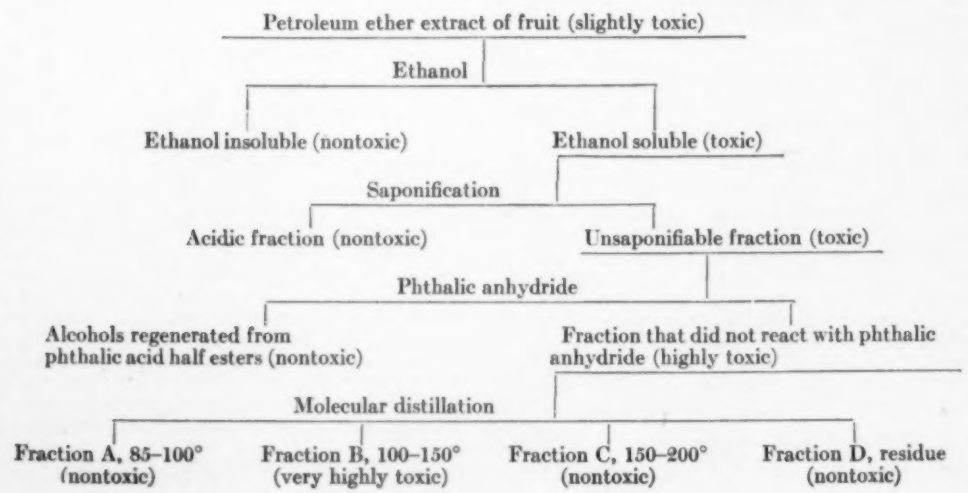
OTHER TESTS WITH HOUSEFLIES.—Other tests with petroleum ether extracts of this fruit showed that the kill of houseflies varies considerably with different lots of the fruit and also with its stage of maturity. When dissolved in acetone at a concentration of 50 milligrams per milliliter, the extract killed on an average about 50 per cent of the flies, but the extract from one lot of fruit gave an 88 per cent kill. On the other hand, when a refined high-boiling kerosene was used as the solvent instead of acetone, the kill was always negligible, and often zero. Since high-boiling kerosene is the solvent in most commercial fly sprays, the use of extracts of *Phellodendron amurense* in such preparations does not appear to be practical.

TESTS WITH *Phellodendron lavalli*.—The fruit of a related species, *Phellodendron lavalli*, was also found to have insecticidal properties. A solution of the petroleum ether extractive at a concentration of 50 mg. per milliliter of acetone was about as toxic to houseflies as an extractive of *P. amurense*.

SUMMARY.—Extracts of the fruit *Phellodendron amurense* showed considerable toxicity to mosquito larvae and when tested in acetone solution to adult houseflies. When dissolved in high-boiling kerosene, such as is used in fly sprays, the extracts showed

[1] The fruit of the *Phellodendron amurense* was supplied by the Division of Hillculture of the Soil Conservation Service.

[2] These tests were made by E. H. Siegler, of the Bureau of Entomology and Plant Quarantine.


Petroleum ether extract of fruit (slightly toxic)
Ethanol
Ethanol insoluble (nontoxic)
Ethanol soluble (toxic)
Saponification
Acidic fraction (nontoxic)
Unsaponifiable fraction (toxic)
Phthalic anhydride
Alcohols regenerated from phthalic acid half esters (nontoxic)
Fraction that did not react with phthalic anhydride (highly toxic)
Molecular distillation
Fraction A, 85–100° (nontoxic)
Fraction B, 100–150° (very highly toxic)
Fraction C, 150–200° (nontoxic)
Fraction D, residue (nontoxic)

practically no toxicity. The commercial use of these extracts for controlling houseflies therefore does not seem practical. Chemical fractionation of the extract gave fractions that were much more toxic to houseflies when tested in acetone than the original extract. A related species, *P. laralli*, was found to have a similar toxicity to houseflies.

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The Relative Effectiveness of Some Corn Earworm Control Measures in Sweet Corn

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A rather widely accepted method for the control of corn earworm in sweet corn is the use of pyrethrins in mineral oil as introduced by Barber (1940). Because of pyrethrum shortage due to the war, other materials have been suggested as toxicants in the mineral oil in place of the pyrethrins, namely, dichloroethyl ether (Barber 1941) and styrene dibromide (Barber 1943).

Results from clipping or de-silking experiments as described by Carruth (1936) and Barber (1938) indicated this method to be unsatisfactory, while Emmert & Price (1942) concluded it was more effective than the pyrethrum-mineral oil treatment.

With the thought in mind of determining the comparative effectiveness of a few of these materials and methods for earworm control an experiment was conducted at University Farm on a late planting of hybrid sweet corn.[1]

The clipping of silks method was compared with styrene dibromide[2] in mineral oil (1 gram per 100 cc. mineral oil, viscosity 125 to 135 seconds Saybolt) and the standard pyrethrum-mineral oil (0.2% pyrethrins) treatment.

One hundred ears were used in each of the following treatments: mineral oil plus pyrethrum; mineral oil plus styrene dibromide; clipping silks; and an untreated check. All treatments were made on August 30, 1943. The stage of development of the corn at that time was approximately six days after silking. This was determined by preliminary observations and is indicated by the ends or tips of the silks beginning to turn brown. The oil-treated ears each received .6 cc. injected by means of a special applicator, and they were tagged in order that only those so treated would be checked at harvest. The clippings from the clipped ears were removed from the field.

The ears were harvested on September 13th and checked for earworm injury. If worms were present in the silks either dead or alive but had not fed any upon the ear proper, it was counted as being clean. The results are as follows:

Mineral oil-styrene dibromide	91.7% clean ears
Mineral oil-pyrethrum	81.6% clean ears
Clipping silks	61.0% clean ears
Untreated Check	21.3% clean ears

SUMMARY—The results of these tests indicate that styrene dibromide (alpha-beta-dibromoethylbenzene) when dissolved at the rate of one gram per 100 cc. of mineral oil, was more effective than .2% pyrethrins in mineral oil or the clipping of silks method for control of corn earworm in sweet corn. The usual ear tip injury observed by previous workers with mineral oil combinations was evident. Clipping was definitely inferior to the oil treatments for earworm control.—10-27-43.

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[1] Furnished through the cooperation of Dr. J. B. Park, Dept. of Agronomy, Ohio State University.

[2] Supplied by the Dow Chemical Company, Midland, Mich.

Mosquitoes of Texas

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Many random mosquito collections have been made in Texas by various individuals. Some of these records have been recorded in literature and others have not. There has been no attempt to compile all of the species taken in Texas into one article. Due to the present national emergency particular attention is being directed toward mosquito control in order to keep down the spread of mosquito borne diseases in and around army camps, naval bases, and war production areas. It is most advantageous to know the species of mosquito that have been reported from an area where mosquito control measures are to be applied. It is with this in mind that this paper

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[2] Ensign, Class H-V(S), United States Naval Reserve.

Table 1.—Mosquitoes taken in Texas and the areas in which they occur.

GENUS, SPECIES	AREAS FROM WHICH RECORDED	BREEDING TIME	ECONOMIC IMPORTANCE
Aedes			
aegypti	All	Throughout year	Transmit dengue, pests
alleni	1, 10	Early spring; summer	None
atlanticus	2, 3	Early spring; summer	None
atropalpus	10	Early spring; summer	None
bimaculatus	1	Spring, summer	None
campestris	15	Early spring through fall	None
gonimus	10	Summer	None
hirsuteron	5	Summer	None
infirmatus	1	Early spring; summer	None
mitchellae	2, 3	Summer	None
nigromaculis	1, 2, 6, 10	Throughout year	Occasional pests
scapularis	1, 10	Throughout year	Important pest (Area 1)
sollicitans	1, 2, 3, 4	Throughout year	Important pests
taeniorhynchus	1, 2, 3, 4, 8	Throughout year	Important pests
thelcter	1, 2, 10	Early spring; fall	Occasional pests
tormentor	3, 4	Early spring through fall	Pests
triseriatus	1, 2, 6, 8, 10, 11	Spring; summer	Seldom pests
trivittatus	3, 6, 10	Spring; summer	None
vexans	1, 3, 5, 7, 8, 10, 11, 12	Throughout year	Important pests
zoosophus	10	Summer	None
Anopheles			
albimanus	1	Throughout year	A pest, possibly transmits malaria
atropos	3	June to September	None
barberi	3	Summer	None
crucians	All except 13, 16, 17	Throughout year	A pest, possibly transmits malaria
pseudopunctipennis	All except 13, 16, 17	Throughout year	A pest, possibly transmits malaria
punctipennis	All except 13, 16, 17	Throughout year	A pest, possibly transmits malaria
quadrimaculatus	All except 13, 16, 17	Throughtout year, at least in south	A pest, transmits malaria
Culex			
abominator	2, 7, 10, 11	Early spring through fall	None
apicalis	3, 4, 7, 8, 10, 11, 12	Fall through spring	None
coronator	1, 3, 7, 8, 10	Throughout year	Pests
erraticus	All	Throughout year	Pests
nigripalpus	1, 2, 8, 10	Throughout year	None
quinquefasciatus	All	Throughout year	Important pests
restuans	1, 2, 3, 4, 6, 7, 10, 11	Throughout year	Seldom pests
salinarius	1, 2, 3, 7, 10	Throughout year	None
tarsalis	All	Throughout year	Pests
thriambus	14	Summer	None
Deinocerites			
spanius	1	Spring, summer	None
Mansonia			
perturbans	1, 4, 8	Spring, summer	Pests in restricted areas
titillans	1	Early spring through fall	Pests
Megarhinus			
septentrionalis	2, 3, 6, 8, 11, 12	Spring, summer	None
Orthopodomyia			
signifera	6, 8, 10, 11, 12	Early spring, summer	None
Psorophora			
ciliata	All except 17	Early spring through fall	Occasional pests
confinnis	All	Throughout year in south	Important pests
cyanescens	All	Summer	Pests
discolor	1, 2, 3, 4, 8, 10	Early spring; summer	Pests
ferox	3, 4, 5, 6, 7, 8, 10	Summer	Occasional pests
horrida	1, 2, 3, 4	Summer	None
howardi	1, 2, 3, 8, 10	Summer	None
signipennis	1, 2, 3, 4, 8, 9, 10	Summer	Occasional pests
Theobaldia			
inornata	All	September to March	None
Uranotaenia			
lowii	1, 3, 4, 10	Early spring; summer	None
sapphirina	1, 3, 4, 10, 11	Early spring; summer	None
syntheta	1 and 10	Early spring; summer	None

has been prepared, and it is hoped that the information included will be of value to camp sanitary technicians and others charged with mosquito control in Texas.

The majority of the species included were taken by personnel of the Texas State Department of Health, and specimens are in the Department collection at Austin, Texas. However, the records and specimens of the Texas Agricultural Experiment Station, College Station, Texas, were made available for study by Dr. F. L. Thomas and Dr. H. J. Reinhard. Captain E. S. Ross, Sanitary Corps, Army of the United States, also contributed valuable information.—9-17-43.

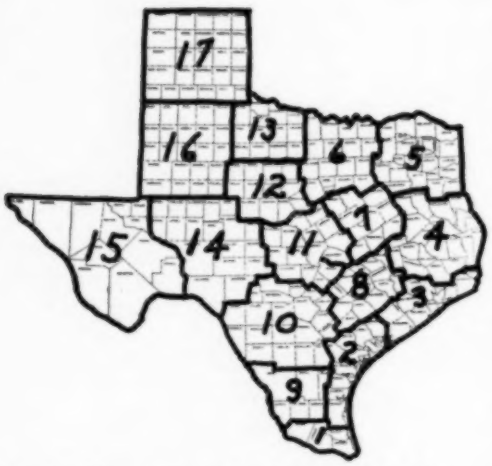

FIG. 1.—Map of Texas showing distributional areas used in recording mosquito collections.

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Some Observations on Chiggers

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The primary purpose of this report is to present results of some observations on the biology of chiggers in central Texas, especially with regard to host and seasonal abundance. The data were collected while the authors were conducting some preliminary tests on chigger prophylactics at Menard.

Eutrombicula alfreddugesi (Oud.) is the predominant species[1] in central Texas and was taken from Angora goats, the coach-whip snake, chicken snake, chicken, dove, chaparral-cock, red-headed sapsucker, horned lizard, armadillo, gray squirrel, and man. This species is most abundant early in the spring and in the fall along wooded stream beds, but for reasons not fully understood it is very numerous during the hot, dry summer months in small isolated areas on high, brushy range land. A tentative explanation is the fact that goats, which are occasionally so heavily infested as to produce sores vulnerable to the screwworm, rest in the shade in such areas, and that infested birds nest and roost there.

The exposure of chicks from 2 to 3 weeks old for 6 to 8 hours in suspected territory was found very satisfactory for locating infested areas and determining the trend of chigger population. Chicks of white-skinned breeds are more desirable for these exposures because of the ease with which the chiggers can be located on them. Such chicks were also found to be very satisfactory for testing chigger prophylactics. Details of these studies will be presented later.

Studies on the length of the larval period show considerable variation, depending on the host. For example on young chicks with a known period of infestation, the length of the larval period averaged 5.9 days, with a maximum of 7 days, whereas on horned lizards collected in nature, the date of infestation being unknown, the average larval period after collection was about 30 days, with a maximum of 65 days. The 65-day maximum period was obtained on a horned lizard collected on July 14 and maintained in a glass jar in the laboratory. Such larval periods during summer months suggest the possibility of chigger larvae overwintering on hibernating hosts. This matter should be investigated.

For the first few hours after detaching themselves from their host, larvae of *Eutrombicula alfreddugesi* are active crawlers, being able to climb perpendicular glass walls. By the end of the first day, however, they become quiescent, the legs are retracted, and no effort is made to attach to the objects upon which they are placed. This facilitates manipulation of specimens.

When placed in dry, stoppered shell vials, some of the larvae transform within 3 days into sluggish, nonreddish, semitransparent nymphs. Others, however, become slightly shriveled, remain quiescent, and molt at irregular intervals for at least 2 months but can be induced to molt over night by addition of a little moisture.

The effect of chiggers on humans is well known. Literature contains but few references on the effect of chiggers on other hosts. In the case of *Eutrombicula alfreddugesi*, some observations have been made that seem worthy of presentation at this time. With birds, Angora goats, and squirrels the reaction seems to be very similar to that produced in man. Reddening of the area involved occurred in armadillo infestations but did not seem nearly so pronounced as the reaction produced in the above-mentioned animals. With horned lizards most of the larvae attached on the ventral and lateral neck folds, producing no noticeable irritation; however, specimens have been observed where several chiggers attached near the eyes and produced sufficient swelling to cause temporary blindness. On snakes the site of attachment was invariably the membrane beneath the scales. No irritation was observed, even on a snake on which more than 5,000 *E. alfreddugesi* were attached.—4-14-43.

[1] *Neoschongastia americana* (Hirst) was present on chickens at both Uvalde and Menard, Tex.

The Chemical Nature of Copper-Arsenic Insecticides

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The first arsenical to come into widespread use as an insecticide was a copper compound, paris green. The literature also contains many references to copper arsenite as an insecticide. In the past few years American manufacturers have brought out two products designated basic copper arsenate and copper hydroarsenate. It is the purpose of this article to acquaint entomologists with the chemical nature of all the copper-arsenic insecticidal products as checked by recent analyses in this laboratory. Since all the compounds discussed are cupric salts, the term "copper" as used herein always refers to that element in the divalent state.

PARIS GREEN.—The nature of this compound is so well known as to need little discussion here. It is generally conceded to be a double compound of copper metaarsenite and copper acetate with a composition corresponding to the formula $3Cu(AsO_2)_2 \cdot Cu(C_2H_3O_2)_2$. This formula calls for the presence of 31.39 per cent CuO, 58.55 per cent As_2O_3, and a molecular ratio CuO/As_2O_3 of 4:3, or 1.33:1.

Fisher & Bailey (1937), in reviewing the analyses (presumably on the "as were" basis) published in the period 1922–1933, record an average of 30.27 per cent CuO for 18 samples, and 55.9 per cent As_2O_3 for 41 samples, including the 18 previously mentioned. This makes the average molecular ratio 1.34:1 and the purity about 96 per cent. Dearborn (1937) later published analyses of 9 samples, a summary of which is included in table 1. In this case moisture determinations were made, which showed the presence of 0.34 to 0.88 per cent, and the results given in the table are calculated to the moisture-free basis. The average molecular ratio again is 1.34:1. There is no reason to doubt the formula generally accepted.

HOMOLOGS OF PARIS GREEN.—Avery (1906) first reported the existence of other complex compounds of arsenic and copper similar in structure to paris green but containing fatty acids other than acetic acid. Dearborn (1935–7) greatly extended our knowledge of this type of compound, making homologs containing the higher fatty acids, such as palmitic and stearic acids. Roark (1942) has reported the results of insecticidal tests made with them. They can be considered as having the composition represented by the general formula $3Cu(AsO_2)_2 \cdot CuR_2$, in which R represents a fatty acid minus one hydrogen atom, and they can be, within limits, either saturated or unsaturated. They have not attained any commercial importance.

COPPER ARSENITE.—The first mention in the Review of Applied Entomology of the use of copper arsenite as an insecticide appeared in 1914. Numerous subsequent references have appeared in that journal, but the compounds used were not definitely identified in any instance.

Table 1.—Analyses of copper-arsenic compounds used as insecticides.[1]

MATERIAL	SAMPLES		CuO	As_2O_3	MOLECULAR RATIO CuO/As_2O_3	WATER-SOLUBLE As_2O_3	MEAN PARTICLE DIAMETER[2]
	Number		*Per Cent*	*Per Cent*		*Per Cent*	*Microns*
Paris green	9	Min.	30.0	56.1	1.33	0.47	15
		Max.	31.1	57.3	1.35	2.12	31
		Av.	30.55	56.86	1.34	1.21	
Copper arsenite	5	Min.	47.0	38.1	3.03	1.1	0.3
		Max.	48.2	38.9	3.13	2.6	1.0
		Av.	47.88	38.46	3.08	2.95	0.5
Copper metaarsenite	3	Min.	27.4	66.3	0.99	0.5	3
		Max.	28.8	69.4	1.08	1.5	—
		Av.	28.13	67.85	1.02	0.82	—
				As_2O_5	CuO/As_2O_5	As_2O_5	
Basic copper arsenate	18	Min.	53.2	36.6	4.01	0.01	0.5
		Max.	55.8	38.7	4.28	0.29	1.6
		Av.	54.46	38.20	4.10	0.10	0.9
Basic copper arsenate+sulfur 1:1	15	Min.	26.1	18.4	4.05	0.07	3
		Max.	27.8	19.8	4.16	0.28	4
		Av.	26.95	18.94	4.11	0.19	3.5
Basic copper arsenate+sulfur 1:2	2	Min.	18.6	13.0	4.13	0.07	5
		Max.	18.8	13.1	4.15	0.14	5
		Av.	18.7	13.05	4.14	0.10	5
Copper hydroarsenate+sulfur 1:1	5	Min.	25.0	16.5	3.93	0.10	0.5
		Max.	26.1	18.1	4.57	0.30	0.5
		Av.	25.3	17.4	4.19	0.21	0.5

[1] Analyses of paris green were made by Dearborn (1937); all other analyses were made by the writers.
[2] The results for paris green refer to that particle diameter, determined by sedimentation, which divides the sample into two equal parts by weight. All other figures refer to surface mean diameter as determined by the air-permeation method.

Since arsenious acid acts in some cases as a polybasic acid, the possibility of more than one type of salt is suggested, and various handbooks record the properties of several supposedly definite compounds. Recently Luchinskii & Churilkina (1940) reported a phase-rule study of the system CuO–As_2O_3–H_2O in which they found evidence for the existence of three types of salt, namely, $Cu_3(AsO_3)_2 \cdot 3H_2O$, $CuHAsO_3$ (without and with 1/2 H_2O) and $Cu(AsO_2)_2 \cdot H_2O$. The last is the compound which, together with copper acetate, constitutes paris green.

Copper arsenite is not widely used in this country, and is not manufactured to any extent as an agricultural insecticide, but it is now attracting renewed attention as a possible larvicide against anopheline mosquities. Five samples obtained recently from chemical supply houses, and known to represent the products of not more than four manufacturers, showed the composition given in table 1. All showed molecular ratios CuO/As_2O_3 close to 3:1, agreeing with the formula $Cu_3(AsO_2)_2 \cdot xH_2O$. We are not convinced that they really consisted wholly of such a compound. Since they must have been made in an alkaline medium, they might contain some cuprous oxide and arsenic oxide coming from the interaction of the original cupric oxide and arsenious oxide, which interaction is known to occur under some circumstances. However, we could devise no scheme of analysis that would unequivocally reveal the true state of combination, and our results, together with those of Luchinskii & Churilkina, force us to conclude at present that there is a "normal" or tribasic, copper arsenate.

Carter & Smith (1941) called attention to peculiarities in the analytical figures obtained on several samples of insecticidal material sold as paris green, and showed that two samples approximated closely to simple copper metaarsenite, $Cu(AsO_2)_2 \cdot H_2O$. These results, together with those for another more recent sample, are summarized in the table and, together with the results of Luchinskii and Churilkina, leave little doubt as to the existence of this compound. So far as we know, copper metaarsenite is being produced by only one manufacturer in the United States.

BASIC COPPER ARSENATE.—One American manufacturer brought out a product under this name about 1939, and since then considerable insecticidal testing with it has been reported. The composition was stated by Witman *et al.* (1939) to correspond to the formula $Cu(CuOH)AsO_4$. The results of our analyses of 18 samples, representing an unknown number of batches, are shown in the table, and approximately confirm this formula. Most of the samples were slightly more basic than the formula indicates, and averaged only about 94 per cent pure. Seventeen other samples of mixtures of the compound with sulfur are also included in the table, and in every case the molecular ratio CuO/As_2O_5 is reasonably close to 4:1 as required by the formula cited.

Another American manufacturer has recently put out a product which he designates "copper hydroarsenate," and which is said (Seibert & Roller 1943) to contain basic tricupric arsenate, $Cu_3(AsO_4)_2 \cdot Cu(OH)_2$. This formula represents the same compound as that just discussed. The copper hydroarsenate is made from arsenic acid, copper sulfate, and lime, and the byproduct calcium sulfate is left in. It is stated to contain from 41 to 46 per cent of the basic arsenate, depending on the temperature at which it is dried. Table 1 shows the results of our examination of five samples of the product. The molecular ratio CuO/As_2O_5 averaged 4.19:1, which is closer to the 4:1 ratio demanded by the formula given than to any other simple formula.

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Di-n-butylamine as a Fumigant

By E. L. MAYER and A. M. PHILLIPS,[1] *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The toxicity of di-n-butylamine against the rice weevil has been shown by Roark *et al.* (1929), who used half-liter erlenmeyer flasks as fumatoria. Ninety per cent of the insects were killed with a dosage of 370 mg. per liter (the maximum dosage tested) and a 24-hour exposure period. In these tests the bottles were placed on the bottom of the flask and covered with 200 grams of wheat. High mortalities were obtained by Hoskins *et al.* (1940) on the third instar of the fleshfly *Lucilia sericata* and by Ralson *et al.* (1941) on adult houseflies in a 30×30×30-inch modified Peet-Grady chamber. Dahm *et al.* (1941), however, reported no appreciable knockdown or mortality against the adult housefly with the large-group Peet-Grady procedure.

Di-n-butylamine is a colorless liquid at all natural temperatures, with a specific gravity of 0.767 at 20°/4° and a boiling point of 161°/C. The material has a strong, rather disagreeable odor.

The results of preliminary fumigation tests in gallon-jar fumatoria made by the writers showed that adults of the rice weevil *Sitophilus oryza* (L.)

[1] Transferred to the Division of Fruit Insect Investigations July 1, 1941.

and the cowpea weevil, *Callosobruchus maculatus* (F.), were very susceptible to the vapors of di-n-butylamine when not in the presence of grain. The beetles were confined in half-inch brass tubing containers, each 3 inches long having 8 rows of thirty-second-inch holes to allow penetration of the vapors. In all tests but one, where a hot-plate was used, the chemicals were allowed to volatilize from filter papers. The exposure period for all tests was 24 hours, and after a lapse of another 24 hours mortality counts were made.

Two types of tests were made to determine the minimum lethal dose under varying conditions. The objects of one series was to ascertain the effect on the beetles alone. A second group of experiments was conducted to compare the penetrative qualities of the chemicals by imbedding cages of weevils in the centers of 4 by 8-inch screen baskets of corn or wheat. Similar tests were made with corn meal in a 600-ml. beaker, with the insects placed at half-inch intervals from the surface. In the latter tests two methods were used to volatilize the di-n-butylamine, one being by use of the filter papers and the other means of a small hot-plate. Other tests were made to determine the effect of a saturated atmosphere on seeds of eggplant, lettuce, carrot, pepper, tomato, and corn.

RESULTS.—The results as presented in table 1 indicate that di-n-butylamine was more efficient than carbon disulfide as a fumigant when insects alone were subjected to their vapors.

Table 1.—Comparison of the effectiveness of di-n-butylamine and carbon disulfide in 24-hour exposure periods.

DI-N-BUTYLAMINE		CARBON DISULFIDE	
Cc. per liter	Per cent mortality	Cc. per liter	Per cent mortality
Rice Weevil			
0.0013	4	0.0053	8
0.0026	69	0.0159	93
0.0053	87	0.0239	100
0.0079	100		
Cowpea Weevil			
0.00026	38	0.0053	13
0.00079	71	0.0106	74
0.00132	97	0.0159	100
0.00212	100		

To obtain 100 per cent mortality of the rice weevil with a minimum of chemical, three times as much (by volume) of carbon disulfide as of di-n-butylamine was required. However, when the dosage is applied by weight rather than by volume, the ratio becomes greater in favor of the effectiveness of di-n-butylamine. Similar comparisons pertaining to the cowpea weevil may be obtained from table 2.

Table 2.—Comparison of minimum lethal doses of di-n-butylamine and carbon disulfide when applied by volume and by weight.

	CC. PER LITER	POUNDS PER 1000 CUBIC FEET
	Rice Weevil	
Di-n-butylamine	0.0079	0.38
Carbon disulfide	0.0239	1.87
Ratio	1:3	1:4.9
	Cowpea Weevil	
Di-n-butylamine	0.00212	0.101
Carbon disulfide	0.0159	1.24
Ratio	1:7.5	1:12.2

Di-n-butylamine is about as effective as carbon disulfide in penetrating grain the size of corn. As the size decreases, however, this property is not so good. Tests with corn meal showed definitely that the penetrative power of this material is very poor, since only the weevils at the half-inch level were affected. At this depth, however, 100 per cent mortality was obtained. Since it took 22 hours for 98.5 per cent of a 4-cc. sample of the material to volatilize from a small piece of celotex, a small hot-plate was employed in this test, about 5 minutes being thus required to volatilize 2 cc. completely from a small beaker. This more rapid method of producing the vapors had no effect on the final mortalities at the different levels. With the use of an equal volume of carbon disulfide at 100 per cent mortality at a depth of 4 inches was obtained. The corn meal turned yellow to the depth of penetration of di-n-butylamine; this discoloration, however, disappeared after the corn meal had stood in an open dish for 2 days.

Fumigation with di-n-butylamine in a saturated atmosphere had very little effect on the germination of vegetable seeds.

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UNDER THE SHADOW of World War II, the science of Entomology stands on the threshold of a new year. When the present conflict had its inception, few of us, I think, realized the importance of the developments of the near future. We are all agreed that the war situation has affected, in varying degree, the work of the average entomologist. To argue against restrictions under conditions such as exist at present, would be as foolish as it would be unpatriotic. Only those who are ignorant of the facts or selfishly unconcerned with the outcome of the present conflict would do so. When this struggle is over, which we all hope will be soon, the entomologist will surely benefit from the important developments which are taking place in insecticide and other researches.

In 1938, I attended, with members of my family, the World Congress on Entomology, held in Berlin, Germany. It was a good congress, and our hosts seemingly were sincere in their efforts to make our stay in Germany both pleasant and profitable. Following the meetings in Berlin, we proceeded to Prague, with Dr. Komarck, Head of the Institute for Forest Protection in Czechoslovakia, and Dr. Hardy, of the Farnham House Laboratory, Imperial Institute of Entomology. I was desirous of visiting areas in Sudetenland where parasites of the European Spruce sawfly had been collected, under Dr. Hardy's direction, for shipment to Canada. Little did we know at the time that German Armies would be marching into Sudetenland six weeks hence. As a matter of fact, soon after we were in Czechoslovakia, the political situation was such as to make it impossible to continue the parasite work and Dr. Hardy was recalled to England.

In addition to the Berlin Congress, it has been my good fortune to represent Canada at other international, or empire, conferences on Entomology, namely at Wageningen, Holland, 1923; London, England, 1925; 1930, and 1935; Ithaca, New York, 1928; Paris, France, 1932; Madrid, Spain, 1935; and Brussels, Belgium, 1938. Attendance at these world and empire conferences resulted not only in the immediate development of projects useful to Canada, but also provided opportunities for keeping the Canadian Entomological Service in continued touch with leading entomologists in different countries of the world.

Dr. L. O. Howard, President of the Ithaca Congress, in his closing remarks to the assembled delegates, said: "The most obvious characteristic of this congress has been enthusiasm. All of us have felt it in an extraordinary degree. It is by far the largest meeting of entomologists ever held and its international character makes it the most important. It has marked to a striking extent the rapidly growing interest in entomology as a science and the widespread appreciation of its importance."

Among the resolutions adopted at the locust conference in Brussels, in 1938, the following related to North America: "The conference records its appreciation of the research and control measures which have been carried out by both the governments of Canada and the United States, and also of researches which have been carried out by scientific institutions in those countries. The conference records its satisfaction at the close collaboration that has been achieved by the entomologists of both Canada and the United States and hopes that this may be maintained."

On a previous occasion the writer stated that entomology in Canada and the United States recognizes no national barriers. For considerably over one hundred years friendly relations have existed between the two countries and no natural science disputes, serious in nature, have developed. James Fletcher, in 1885, stated that "from the geographical position of Canada and the United States many of our interests and theirs are naturally identical." F. M. Webster, in 1898, said:

"In all these matters, Canada and the United States are one, and this being true, there must be no lines of separation between the entomologists of these two countries." Howard, in 1930, referring to cooperation between the Canadian service and that of the United States, stated: "Nothing could be more ideal than the conditions, in this respect, that have existed. . . . Our problems are the same; our ends are the same; and, of course, we are aided in this community of spirit by the common language and by similar methods of training."

During my term of office as Dominion Entomologist (1920–42) I have always welcomed opportunities for the holding of conferences between Canadian and United States entomologists. Many such have been held. These undoubtedly resulted in much benefit to workers of both countries. The European Corn Borer Conferences held in September 1926, at Chatham, Ont., and Detroit, Mich., as I stated several years ago, illustrated a most interesting and valuable advance in international cooperation. Probably at no previous time in the history of applied entomology had there been such a joint effort to devise ways and means of defeating an insect which had developed into an extremely important international menace.

The Imperial Institute of Entomology, through the Colonial office, has called conferences in London, to which the Chief entomologists of the overseas Dominions and Colonies were invited. These conferences have been at five-year periods, namely: in the years 1920, 1925, 1930, and 1935. At each conference the whole work of the Institute was reviewed and discussed by the delegates, and in addition contributions on various subjects of entomological research of value to workers throughout the Empire were presented. Owing to present world war conditions no conference of this series has been held since 1935.

As the science of entomology develops in future years, and this troubled world resumes peacetime activities, so too will friendly cooperation continue not only between the entomologists of the United States and those of Canada, but of other countries as well. Other world congresses will surely be held. At these, new contacts will be established and, through cooperative effort, results of widespread importance will undoubtedly follow. No lack of opportunity for research in the field of insect control will await the entomologist of the future.

ARTHUR GIBSON

Ottawa, Canada

FROM WILLIAM R. HORSFALL

I write to you as a representative of the American Association of Economic Entomologists to wish the Association well on the eve of another annual meeting. My memories of past meetings have been of the most pleasant.

A bit of personal history might be useful in the file of the Association. I am the Commanding Officer of a malaria survey unit in the Southwest Pacific Theatre of War. The unit has been in the field for nearly three months making collections and observations on *Anopheles* abundance. No better assignment could have been given an entomologist.

Lt. Colonel W. V. King is stationed here. His has been a great work in showing the value of having trained entomologists in this Theatre.

Very truly yours,
William R. Horsfall

Lt. W. R. Horsfall, O-513051
17th Malaria Survey Unit
APO 928, San Francisco, California
November 9, 1943 (V-Mail)

RESEARCH FUND TO HONOR T. J. HEADLEE

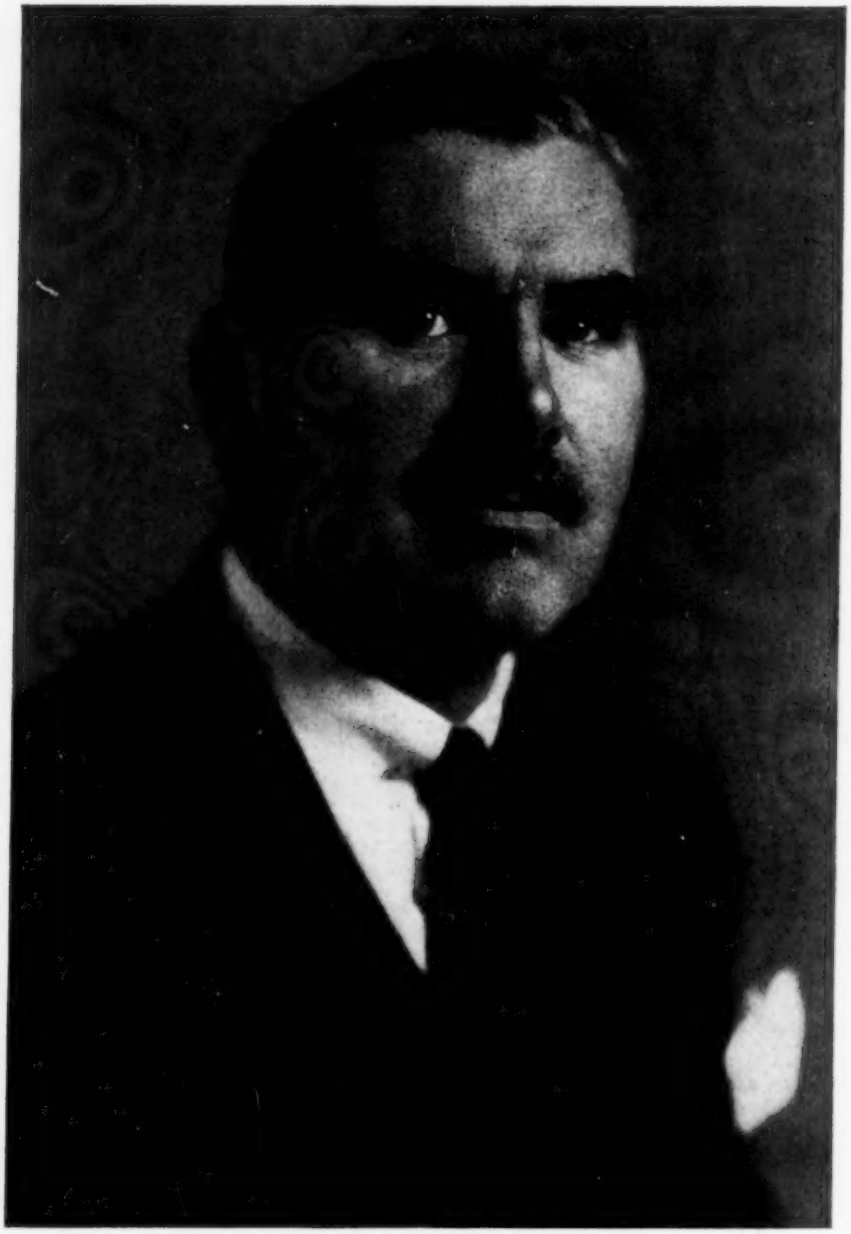
Establishment of a Thomas J. Headlee Research Fund in Entomology was announced at New Brunswick on January 14 at a tea given in tribute to Dr. Headlee who recently retired as head of the entomology department of the New Jersey College of Agriculture and Experiment Station to become professor emeritus of Rutgers University.

Announcement of the fund was made by Dr. William H. Martin, dean and director of the institution, who reported that it will be used to offer fellowships to students at Rutgers who show special promise of achievement in basic entomological research.

"This endowment is being established with two practical aims in mind," Dr. Martin said. "The first is to stimulate basic research designed to enlarge our knowledge of entomology, and the second to promote interest among students in pursuing the fundamental studies in entomology which are most likely to equip them for constructive service in the ever-widening field of applied research."

The tea given in Dr. Headlee's honor was attended by many county Extension workers as well as other Rutgers staff members who worked with him from time to time during his 31 years with the University.

OBITUARIES



Leonard Septimus McLaine, 1887-1943

Dr. McLaine was born in Manchester, England, June 27, 1887 and died July 20, 1943 at his summer home, Lake Bernard, Quebec. At the time of his death he was the Dominion Entomologist and also Assistant Director of Science Service in Canada.

His early education was obtained in North Wales. About 1897 he with his father and sister came to New York where his sister married, his father returning to England soon afterward. Following studies at the Wilson Lyon School in New York City he entered Boston University, but finding that his interests lay in a different direction he transferred to the Massachusetts State College, graduating there in 1910, receiving the Bachelor of Science degree, and was appointed a graduate assistant there, specializing in entomology. Two years later he received the degree

Master of Science, based on original research during that period and became a Massachusetts deputy State nursery inspector for a year.

In 1913 he was engaged by the Entomological Branch, Canada Department of Agriculture, as a field officer in charge of the brown-tail moth survey with headquarters at Fredericton, N. B. where he remained until 1919 when the Branch was reorganized into four divisions and he was appointed Chief of the Division of Foreign Pests Suppression and also Executive Assistant to the Dominion Entomologist, Dr. C. Gordon Hewitt, with headquarters at Ottawa.

In 1923 a Destructive Insect and Pest Act Advisory Board was established and Dr. McLaine's administrative ability had been so evident and his work so satisfactory he was chosen Secretary of the Board and served as such until 1942, in charge of the administration of the Act. This included the direction of a large inspection staff of workers, but in 1933 he was also made Secretary of the newly established Federal Apple Maggot Advisory Committee to supervise the eastern export trade in apples.

In 1938 a reorganization of the Canadian Department of Agriculture resulted in the appointment of Dr. McLaine as Chief of the Plant Protection Division. This not only continued his duties with the former Division of Foreign Pests Suppression and the Apple Maggot Advisory Committee but added to them the administration of the Seed Potato Certification Service.

On January 15,1942 he was appointed Acting Dominion Entomologist, followed July 16 of that year at the retirement of Dr. Arthur Gibson from that office, as Dominion Entomologist and also Assistant Director of Science Service, positions which he held until his death.

He was a member of the American Association of Economic Entomologists and was its President in 1936; a member of the Entomological Society of Ontario and its presiding officer in 1936–37; a Fellow of the American Association for the Advancement of Science; a member of the Ottawa Field Naturalists; of the Quebec Society for the Protection of Plants (its President in 1939); and of the Canadian Society of Technical Agriculturists, in all of which he took an active part.

Dr. McLaine's work in his chosen field soon became largely administrative but his interest in Entomology itself remained strong and in the investigations of those whose work he supervised he was always sympathetic and encouraging. But his interests were also broad in civic and in national affairs. From 1937 to 1943 he was a member of the Council of the village of Rockcliffe where he made his home and was a charter member of the Professional Institute of the Civil Service of Canada in which he was very active, being its Honorary Secretary in 1927–28 and President 1930–31 and also representing the Institute on the Advisory Committee on Superannuation from 1937 to 1943. In July, 1932 he attended the Fifth International Congress of Entomology at Paris as a Canadian representative and he also made several trips to Great Britain in connection with his work.

But the work he loved the most was concerned with the protection of Canadian agriculture from the ravages of insects, both native and introduced and he frequently visited the United States to keep in closer touch with what was being done there and to promote cooperation of the two nations along these lines.

His ability and the value of his work resulted in the action of the trustees of the Massachusetts State College conferring upon him May 23, 1943 the degree Doctor of Science "in recognition of his accomplishments and meritorious service in the field of Entomology."

After receiving this degree he went to New York to visit his sister and while there was taken quite ill. He therefore returned to Canada to rest at his summer home where he died a year and six months after becoming Dominion Entomologist.

His death marks the end of a most successful career which had promised to continue in wider fields for years to come.

Besides his wife, Kathleen, he leaves three children and many friends who knew and loved him well. He was a friendly man, a quick thinker and clear speaker and his passing is not only a great loss to all who knew him but also to the field which he made his life work.

H. T. FERNALD

Wilmon Newell, 1878-1943

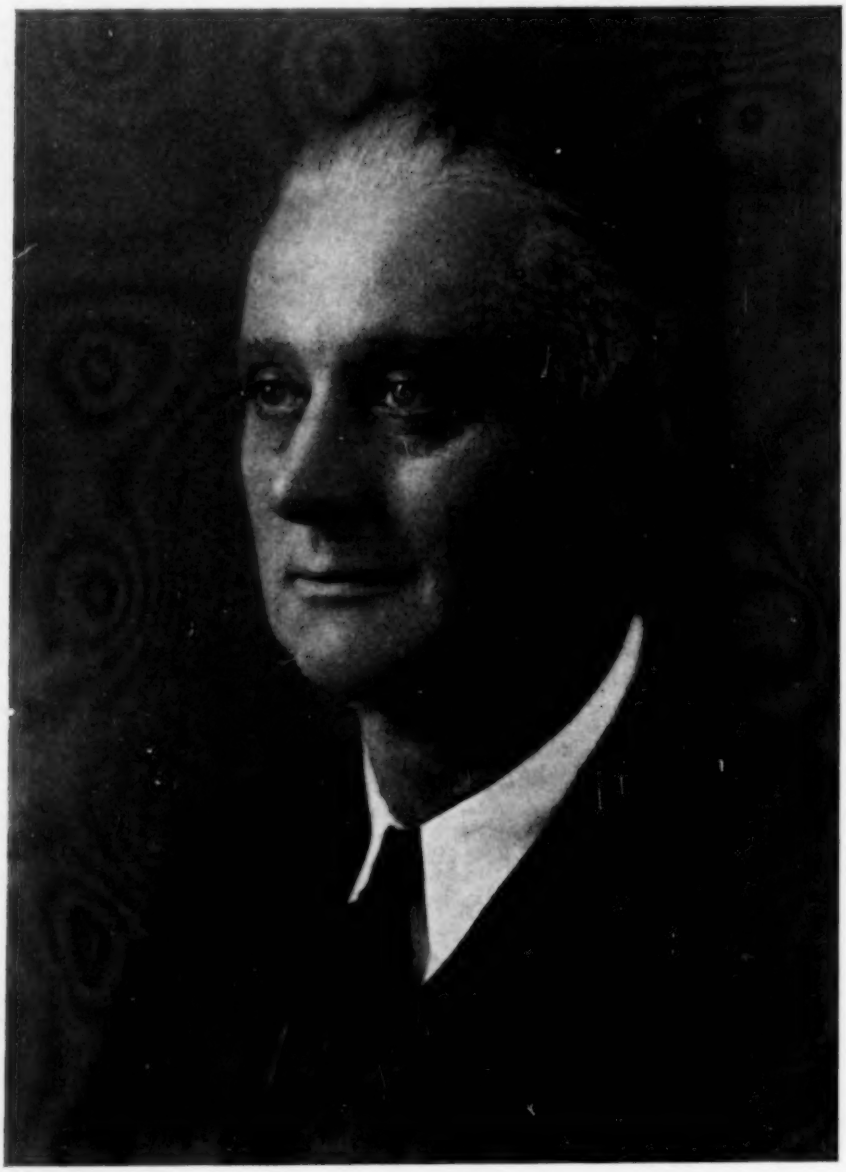
Wilmon Newell, provost for agriculture at the University of Florida, died at his home in Gainesville at 8 p.m. on Monday, October 25, 1943. He is survived by his wife, Helen (Mabee) Newell and his stepmother, Mrs. W. J. Newell of Hull, Iowa. He had been seriously ill for a period of a year. Funeral services were held in Gainesville on October 29. The Masonic Lodge of Gainesville conducted the burial services. The American Association of Economic Entomologists was represented at the funeral by W. G. Bruce of the Bureau of Entomology and Plant Quarantine and John T. Creighton of the University of Florida.

Wilmon Newell was born in Hull, Iowa March 4, 1878, the son of William James and Elizabeth (Anderson) Newell. His mother was born in Virginia and his father in Nottingham, England.

He secured his grammar and high school education in the grade schools of Hull, Iowa, entered Iowa State College in 1894, and received the Bachelor of Science degree in 1897, and the Master of Science in 1899. This institution conferred the Doctor of Science upon him in 1920, and the same degree was conferred upon him by the Clemson Agricultural College in 1937. He married Helen Mabee of Galesburg, Illinois, in 1907.

In 1898, Wilmon Newell became Deputy Entomologist on the staff of the Department of Entomology of the Iowa Experiment Station under Dr. Herbert Osborn. In this capacity he served in part as a nursery inspector, thereby securing his first professional contact with the plant quarantine phase of entomology. He went to the Ohio Experiment Station at Wooster in 1899, and served there as an assistant to Professor F. M. Webster until 1902 when he went to Texas as Assistant Entomologist and Apiarist of the Texas Experiment Station. He continued in these two capacities until 1903, when he became State Entomologist of Georgia. In 1905 Dr. Newell was appointed Entomologist of the Louisiana Experiment Station and Entomologist and Secretary of the State Crop Pest Commission.

In 1910 he returned to Texas as Professor of Entomology and Experiment Station Entomologist at the Texas Agricultural and Mechanical College. In 1915, he was called to Florida to serve as the first Plant Commissioner of the newly created State Plant Board. He served as Commissioner until the time of his death. In 1921, the Florida State Board of Control appointed Dr. Newell to be Dean of The College of Agriculture, Director of the Florida Experiment Station, and Director of the Agricultural Extension Division. In 1938, he was appointed Provost for Agriculture at the University of Florida, and continued in this capacity until death.



Wilmon Newell

Dr. Newell's career is studded with outstanding scientific achievements. His first publication was issued in 1898. This paper was entitled, "A New Species of Aspidiotus." Later he published several other papers dealing with the Coccidae. Before his career was terminated, he wrote more than one hundred and seven scientific papers dealing with apiculture, cotton insects, scale insects, and quarantine and eradication methods.

In Louisiana, between 1905 and 1909, he made some of his finest research contributions. The cotton boll weevil was spreading eastward. Dr. Newell and his associates made careful control studies. Dr. L. O.

Howard, in his "History of Applied Entomology," wrote: "His name stands out among the workers on the cotton boll weevil for the reason that in 1907, in Louisiana, he first tried powdered lead arsenate against the boll weevil. Large field tests followed in 1908 and 1909. This was the first use of an arsenate in powder form against the weevil, and undoubtedly led naturally and directly to the development of calcium arsenate." He also conducted history-making investigations with poisoned led arsenate bait as a boll weevil poison. The Argentine and appeared in New Orleans during his period of service in that state, and it was his research which served as a basis for the control, and in some localized instances the eradication, of this important pest.

When Dr. Newell came to Florida in 1915, he was charged with the responsibility of directing the efforts to eradicate the citrus canker. His great organizational ability was quickly revealed as he carefully trained his newly employed personnel, and plotted the course of action to be taken. This eradication was successfully completed, and the Florida State Plant Board became a model for the creation of similar organizations in other states. Because of his singular eradication success with citrus canker, the administrative officers of the Plant Quarantine and Control Administration of the United States Department of Agriculture, in 1929 urged him to serve as Field Director of the eradication campaign against the Mediterranean fruit fly in Florida. He accepted and the strenuous campaign which he organized and directed will serve as model for eradication efforts of the future. He put all of his tremendous energy into this war against a dangerous agricultural foe, and the battle left permanent scars upon him physically. Scientific workers throughout the world recognize Wilmon Newell as the dynamic factor in the elimination of this destructive pest from the North American continent.

Dr. Newell's executive ability resulted in his being called to positions of administrative prominence. He has been recognized as one of the ablest agricultural administrators of his time. In his capacity as Dean of the University of Florida College of Agriculture, he was instrumental in its advancement to its present prominence. Serving as Director of the Florida Experiment Station he was the driving force back of the introduction of the tung tree and instrumental in the establishment of the southeastern tung industry. Many noteworthy research accomplishments have been completed by the Florida Experiment Station under his direction.

The foregoing brief résumé of some of the professional accomplishments of this great entomologist indicates the prominence which he attained through innate ability and hard work. He gave his very life to his work and his only regret as he faced the end of his journey was, in his own words, "that I shall not be permitted to do the many other things that I had planned for Florida agriculture and for my associates." His success was in great part due to his devotion and loyalty to the State of Florida and to his professional associates. He built his organizations upon loyalty. He was loyal to all of his employees and in turn demanded their loyalty to the State and its agricultural administration.

Those of us who were privileged to know this great man intimately, encountered in him striking qualities of human warmth, and a cleanness of spirit which resulted in a response of affection. He had a deep interest in the development of young scientific workers and served as their invaluable adviser. He had a tender regard for the unfortunate. In the words of Dr. Dwight Sanderson, "I remember his personal generosity. There were poor families around College Station, Texas, which Newell helped—often with cash loans—in ways which only later were revealed."

Doctor Newell attained many honors. He was a member of the advisory council of the Southern Forestry Experiment Station, of the United States Forestry Service; fellow of the American Association for the Advancement of Science; member of the Entomological Society of America; member, and president in 1920, of The American Association of Economic Entomologists; charter member of The Cotton States Branch of the Association; member, and president in 1929, of The Association of Southern Agricultural Workers; University of Florida representative of The Institute for Research in Tropical America; member of the Soil Science Society; administrator of Florida State Soil Conservation; chairman of The Florida Land-Use Planning Committee; and chairman of The Advisory Committee on Agriculture of The Florida Defense Council since 1941. He was also a Mason and a Shriner; a Member and past president of the Gainesville Rotary Club; member of Kappa Sigma social fraternity; and member of the honorary fraternities of Alpha Zeta, Phi Kappa Phi, and Gamma Sigma Delta. The students in the Department of Entomology of the College of Agriculture held him in such high esteem that they named their professional society the Newell Entomological Society in his honor. Subsequent to his death the Florida State Board of Control and The State Board of Education, at the direction of Governor Spessard L. Holland, dedicated the rebuilt Agricultural Experiment Station Building on the University Campus as a memorial in his honor. Henceforth, it will be known as Newell Hall.

In the passing of this great leader, the science of entomology has lost one of its most eminent members, and Southern agriculture one of its greatest leaders.—12-7-43.

JOHN T. CREIGHTON

DR. FRANK E. LUTZ

Dr. Frank E. Lutz, of the American Museum of Natural History, died at the age of 64 years, on November 27, 1943.

Dr. Lutz has been, for twenty-two years, curator of insects and spiders in the Museum. He is best known to students of Entomology through his, "Field Book of Insects," but has contributed to the science of Entomology in many and varied ways.

HUGH KNIGHT

Word has recently been received that Hugh Knight, a member of our Association residing in Glendora, California, died of a heart attack on October 9, 1943. It is hoped that the *Journal* may be able to secure a more extended account of the activities of Mr. Knight for later publication.

Ephraim Porter Felt, 1868-1943

Dr. Felt was born at Salem, Massachusetts, January 7, 1868. He was the son of Charles Wilson Felt and Martha Seeth (Ropes) Felt. He attended the public schools and being ambitious and industrious, worked on farms and in other capacities during his youth. He graduated from the Massachusetts Agricultural College at Amherst in 1891 with the degree of B.S. having specialized in entomology under Professor Charles H. Fernald, and also received a degree of B.S. from Boston University.

In 1891 he was appointed an assistant to Professor Fernald, who was also Entomologist to the Massachusetts Board of Agriculture, and carried on experimental and other work on the gypsy moth during that year. He was a fellow at Cornell University in 1892 and 1893 and received the degree Sc.D. from that institution in 1894. From 1893 to 1895 he taught the natural sciences at the Clinton Liberal Institute at Fort Plain, New York, and was appointed assistant to the State Entomologist of New York, Dr. J. A. Lintner, in 1895. On May 5, 1898 Dr. Lintner died suddenly while in Rome, Italy, and Dr. Felt was appointed Acting State Entomologist. Later in the year he was appointed State Entomologist, a position which he filled with distinction for thirty years.

Dr. Felt married Helen Maria Otterson in 1896. She died at Stamford, Connecticut, in 1939. His home for many years was at Nassau, Rensselear County, near Albany where he participated in many activities of the town, being particularly interested in the schools and civic affairs, and during World War I was active in Liberty Loan drives and other patriotic services. In 1910 he spent six weeks in Europe giving special attention to museum methods, shade and forest tree insects and the gall midges. Collections were studied in the following institutions British Museum of Natural History, London; the Universities of Oxford and Cambridge; the Tropical School of Medicine, Liverpool; the zoological gardens at Antwerp; the Royal Museum of Natural History at Brussels; the botanical gardens of Ghent; Museum of Natural History and also the entomological station, both of Paris; the University at Zurich; the exceptionally valuable collection of forest insects in the forestry school at Munich; the natural history collections in the Senckenberg Museum at Frankfurt; the Winnertz collections in the University of Bonn; the Museum of Natural History, Berlin, and the Museum of Natural History at Hamburg. He also conferred with many specialists during this European trip from whom he secured ideas relative to insect work which, in some cases, were applicable to problems in this country.

From 1898 to 1911 he was the Entomological Editor of the *Country Gentleman*. He was an ardent supporter of the theory that many diseases are spread by house flies and mosquitos, and carried on experimental work for the purpose of attacking diseases by the indirect method of controlling insect carriers.

In addition to his duties in connection with the State Museum with which he was officially connected, he cooperated for many years with the State Department of Agriculture and gave invaluable advice relative to many and varied insect problems, particularly concerning nursery and orchard inspection which was handled by that Department. He cooperated with Cornell University and with the Department of Entomology of that institution and with the Entomological Department of the New York Agricultural Experiment Station at Geneva and Syracuse University at Syracuse, New York. His activities extended far beyond these official connections as he constantly gave advice on insect problems, not only to other state and city departments by means of publications, interviews and lectures, but also to the public both within and beyond the limits of the State.

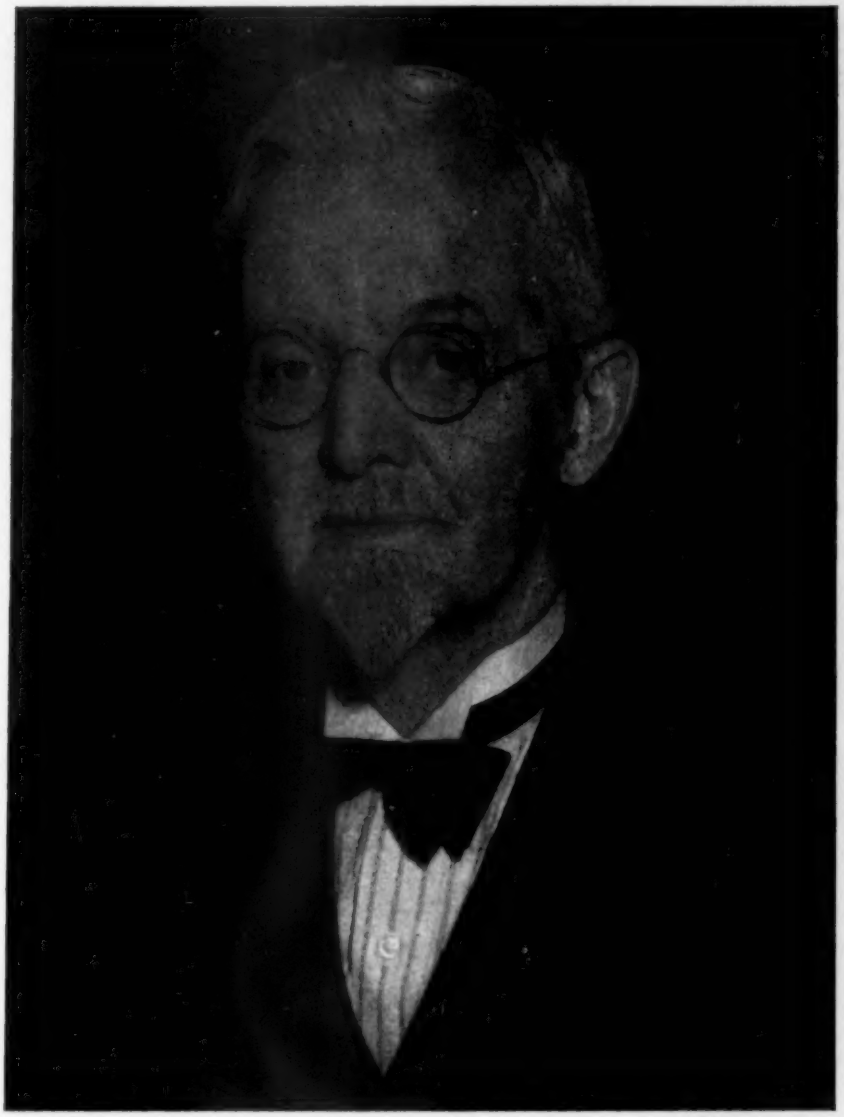
In 1923 and 1924 he acted as Chief Entomologist to the State Conservation Commission and carried on research relative to the gypsy moth and other pests which attack forest and part trees. At the close of his work as State Entomologist in 1928 he became Director and Chief Entomologist to the Bartlett Tree Research Laboratories at Stamford, Connecticut, where he continued until December 14, 1943, when he died suddenly in his office of a heart attack.

While State Entomologist he published 25 official reports covering the activities of that office and many bulletins which were published by the New York State Museum, also more than 700 important and timely papers and articles which included a wide variety of entomological work including general entomology as well as popular articles of an informative nature for the general public. He was a frequent contributor to entomological journals and scientific publications as well as farm magazines and newspapers. He also found time to give numerous addresses, to publish several popular books, and to speak over the radio on different phases of entomological activities. His published reports and bulletins were models of systematic arrangement and clarity of expression and were usually accompanied by complete bibliographical references which made it possible for the reader to secure further information from other published literature. Many bulletins during this period were outstanding. Among them might be mentioned two large volumes on "Insects Affecting Park and Woodland Trees" with 118 full page plates, several of them in colors. His taxonomic work on groups of little known insects contributed greatly to the knowledge of many families, genera and species in fields which had not been explored. More than "a five-foot book shelf" would be required to file the valuable publications written by him.

He was an emeritus life member of the American Association for the Advancement of Science, a member of the Entomological Society of Washington, New York Entomological Society, and an honorary member of Entomological Society of Ontario. In 1901 he received one gold and three silver medals from the Pan American Exposition, Buffalo, New York, for his scientific contributions and in 1921 was listed in American Men of Science as one of the thousand of outstanding scientific men in the United States. He was a member of Sigma Xi and a charter member and fellow of the Entomological Society of America. In 1913 he gave the annual public address on Gall Insects before this society at Atlanta, Georgia. In 1914 he was elected a member of the American National Committee on Nomenclature of the Second International Congress In 1916 he was elected Vice President of the society and in 1923 was a member of its Executive Committee. Since 1897 he has been an active member of the American Association of Economic Entomologists, its President in 1902, and has served on many of the

important committees. In the last 45 years he has seldom missed a meeting of this organization. He was active in forming the Eastern branch of the Association and materially contributed to the success of its meetings.

In 1907 the Association faced one of the most severe crises in its history. The United States Department of Agriculture had, up to that time, published the annual reports of the Association as bulletins of the Bureau of Entomology. Conditions arose so that this arrangement was discontinued and, as the Association at that time had a balance of only $50.12 in the treasury, the outlook for publishing the annual report was most discouraging. However, at that meeting a publishing company was organized among the members to which non-interest bearing stock was sold at $10.00 a share to finance a publication to take care of the annual reports of the meetings and to publish a limited number of important papers which might be presented during the year. The company agreed to publish six numbers annually at a subscription price of $1.00 per annum to each member and $2.00 to non-members, the publication to be the official organ of the Association. This proposal was made by Professor E. D. Sanderson and arrangements were perfected so that on re-



Ephraim Porter Felt

payment to the stockholders all property belonging to the company, including back numbers, would revert to the Association.

Dr. Felt was elected Editor, the writer, Associate Editor, and through the energy of Professor Sanderson, who was made business manager and Wilmon Newell, who consented to become advertising manager, together with L. O. Howard, James Fletcher, Henry T. Fernald, S. A. Forbes, H. A. Morgan and Herbert Osborn, who were elected as the advisory board, the publication was launched as the JOURNAL OF ECONOMIC ENTOMOLOGY and the first number published in February, 1908. In 1911 the indebtedness incurred had been paid from JOURNAL receipts and the publication and its assets turned over to the Association. Dr. Felt continued as Editor until 1935 when he retired at his own request and was made honorary editor which position he held until the date of his death.

He also accepted the responsibility of the editorship of the Index to the Literature of American Economic Entomology which was published by the Association, the data being compiled by Miss Mabel Colcord, Librarian of the Bureau of Entomology. Five volumes have been published under his editorship covering the years from 1921 to 1939 inclusive, aggregating 2855 pages, the last volume being under the joint editorship of Dr. Felt and Dr. S. W. Bromley. These books are invaluable to all working entomologists and were largely made possible through the generous cooperation of the Bureau of Entomology and its specialists and the untiring energy and devotion of the editor.

In connection with his editorial work, Dr. Felt also served on the supervisory board of the American Year Book, was a frequent contributor to the *New York Times* and other newspapers and magazines, and was a member of the National Shade Tree Conference of which he was chairman in 1928 and edited many of their reports.

A conference called by the Commissioner of Farms and Markets of New York was held in Albany, New York, in 1922, for the discussion of the gypsy moth problem and was attended by representatives of the New England States, New York and New Jersey, the United States Department of Agriculture, the Bureau of Entomology, the Federal Horticultural Board and the office of the Dominion Entomologist of Canada. Dr. Felt presented a plan for checking the spread of the gypsy moth which resulted in the establishment of the Barrier Zone in western New England and eastern New York to prevent the spread of this insect. This met with the approval of the conference and has been operated since that time with great success in preventing the normal westward spread of this insect. At various times he advocated vigorous measures for the control of the European Corn Borer, the Japanese Beetle, the Elm Leaf Beetle and the Dutch Elm Disease. He was for several years a collaborator of the United States Bureau of Entomology and was active in carrying on experimental work in connection with different phases of these problems.

Since Dr. Felt's association with the Bartlett Tree Research Laboratories, he has had an opportunity to concentrate his efforts on research on insects affecting trees. He has been the author for the last twelve years of a weekly syndicated newspaper article entitled, "Talks on Trees" which has been used by nearly 300 newspapers throughout the country, and has been a frequent speaker before horticultural societies and garden clubs, as well as over the national broadcasting network.

In 1938 he published a book entitled "Our Shade Trees"; in 1941, "Pruning Trees and Shrubs"; and in 1943, "Shelter Trees in Peace and War." He has made studies of collections of insects taken on airplanes; also the European Bark Beetle as a carrier of the Dutch Elm Disease, and determined that this insect is capable of being carried long distances by the wind.

The report of a collection of insects taken by him from the 86th floor of the Empire State Building in New York City aroused considerable interest as well as experiments in releasing toy balloons to obtain data on the possible trend of spread of insects by the wind. Dr. Felt had a keen mind, possessed great ability in detecting the vital points in any problem, and attacking them constructively. He always welcomed suggestions and was steadfast in maintaining his opinion once he was convinced that his conclusions were correct. He had the rare ability, while holding his own opinions, to concede the same right to others and was endowed with patience when participating in discussions of a controversial nature. He approached problems in the spirit of helpfulness and will long be remembered by many who have sought his counsel and advice on difficult problems. He was a tireless worker, had great ability as a writer and was also able to concentrate his efforts so as to accomplish the maximum amount of work in a short period of time; otherwise, he could not have attempted the multitude of tasks on which he worked. The value of his services to the public will never be fully appreciated, but those who knew him best marvel at the volume and quantity of work which he could do with so little apparent effort. He had few assistants in his office during his entire career.

He is survived by a sister, Miss Elizabeth A. Felt of Brookline, Massachusetts; two brothers, George H. Felt of Northboro, Massachusetts, and Benjamin F. Felt of Melrose, Massachusetts; a son, Ernest Felt of Utica, New York; three daughters, Mrs. Charles Deane of Summit, New Jersey; Mrs. Helen F. Peschel of Oak Ridge, Tennessee; Mrs. Margaret Hunter of East Schodack, New York; and 13 grandchildren.

A great man and a great entomologist has passed on but his devotion to duty and the outstanding service which he performed in his chosen field is immeasurable. The influence which he had on the progress of Economic Entomology will remain, and the work of his brain and pen leaves with us a living monument which even the hand of time cannot erase.—A. F. BURGESS.

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